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EDITED BY J. McKEEN CATTELL

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THE SCIENTIFIC MONTHLY

SEPTEMBER, 1924

HEREDITY AND ENVIRONMENT

By Professor H. S. JENNINGS

THE JOHNS HOPKINS UNIVERSITY

KNOWLEDGE of heredity has changed fundamentally in the past few years; in consequence the relations of environment to heredity have come into a new light. What has gotten into the popular consciousness as Mendelism—still presented in the conventional biological gospels—has become grotesquely inadequate and misleading; its seeming implications as to the trivial rôle of the environment have become null and void.

What happens in any object—a piece of steel, a piece of ice, a machine, an organism—depends on the one hand upon the material of which it is composed; on the other hand upon the conditions in which it is found. Under the same conditions objects of different material behave diversely; under diverse conditions objects of the same material behave diversely. Anything whatever that happens in any object has to be accounted for by taking into consideration both these things. Neither the material constitution alone, nor the conditions alone, will account for any event whatever; it is always the combination that has to be considered.

Organisms are like other objects in this respect; what they do or become depends both on what they are made of, and on the conditions surrounding them. The dependence on what they are originally made of we call heredity. But no single thing that the organism does depends alone on heredity or alone on environment; always both have to be taken into account.

What an organism is first composed of comes directly from its parents; this is the reason why dependence on that composition has been called heredity. But this habit of speech has led to conceiving heredity as something in itself, an entity, a "force," something that itself does things—an error that has induced clouds of misconception. Possibly we should be better off with no such concept as heredity: then analysis would be correctly directed toward under-

standing, in organisms as in other things, in what ways there is dependence on the stuff they are made of: in what ways on the conditions in which that stuff is found.

As to the dependence on the stuff that they are made of, research has shown that the substances passed from parent to offspring, giving rise to the phenomena of inheritance, are a great number of discrete packets of diverse chemicals, imbedded in a less diversified mass of material. The masses formed by the grouping of these packets are visible under the microscope as the chromosomes. The number of different kinds of packets that go into the beginning of any individual is very great, running into the hundreds or thousands. They are not massed in a haphazard way, but are arranged in a definite manner; so that the young organism is like a well-organized chemical laboratory with many reagents so arranged in containers as to react with each other in an orderly way, producing a definite and harmonious result.

Development we know consists in this orderly interaction of these substances—with each other, with the rest of the cell body, or cytoplasm; and with the oxygen, food and other chemicals brought into the cell from outside; all under the influence of the physical agents of the environment. The final result—what the individual becomes—is dependent upon all these things; a change in any of them may change the result.

The disposition of the chemical packets, or genes, is known to be at the beginning that of a double serial arrangement, like a pair of strings of beads; each chemical has its precise and practically invariable place in the series. For each packet in one of the two strings there is a corresponding packet in the other, so that the whole forms a set of pairs of packets. The two corresponding packets of one pair may both contain the same chemical. More commonly, perhaps, they contain chemicals somewhat diverse, though of related character; every individual has a great number of such pairs with diverse chemicals in the two packets.

When the organism becomes a parent, these sets of packets are distributed to the offspring according to a simple plan. The laws of heredity are in the main simply the rules of distribution of the packets. One parent gives to any particular offspring one packet only of each of its pairs. The other parent supplies the corresponding second packet of the pair, so that the offspring has again the full complement of pairs. The first of the rules of distribution discovered was the so-called Mendelian Law; it is the rule according to which the two packets belonging to the same pair are distributed. But when we take into consideration the interrelations of packets belonging to different pairs, a whole set of rules is discovered, cov-

ering the distribution of all the packets. These have been worked out in recent years: they are of equal importance with Mendel's Law. In essence all these laws are simple; any set of beads or buttons can readily be put through the same simple operations, and then they yield the same rules that we call the laws of heredity. But for genes located in different parts of the system, the rules of inheritance are somewhat diverse; and some of the genes are not paired, so that they yield a set of rules very different from those followed by the others. The only way to grasp the laws of inheritance is to arrange a set of objects in the way the genes are arranged and to put them through the simple movements followed by the genes; attempts to understand them in any other way are futile. The laws of inheritance are not immediate consequences of some fundamental physiological principle, but of the arrangement of the packets of chemicals and their method of distribution. Where the arrangement is different, there are other laws. For many kinds of reproduction, on this account, nothing resembling Mendelian inheritance occurs. But as the rules work out in most cases of biparental inheritance, every germ cell gets a different combination of these packets of chemicals from that obtained by any other, so that in consequence every individual starts out as a different combination of chemicals from every other; this makes prediction of results more hazardous in this field than is sometimes represented.

Any correct notion of the relation of environment to heredity depends on proper knowledge of how these packets of chemicals operate in producing the developed organism. This knowledge is obtained in two ways. One is by direct study under the microscope of the changes that occur during development, with experiments on the developing embryo. The other is by interchanging the different packets of chemicals and noting the consequences. In certain organisms it has become possible by proper mating and breeding to control the distribution of the packets almost as if they could be picked out and moved about by hand; this is essentially what is done by Morgan and his associates in their work on Drosophila.

Substituting one or more packets for others is found to change the characteristics of the organism produced; different sets give when they develop, even under similar environments, different physical, mental and moral peculiarities. The first precise discovery made was, essentially, that when a single one of the packets is exchanged for another, some definite later character is changed. So, changing one packet alters the color of the hair from black to red; or changes the eye color from blue to brown; or makes the organism short instead of tall; or even changes a person from a normal individual to a feeble-minded one; or the reverse. Characters changed by altering a single packet were the so-called "unit

characters" of Mendelism. These facts—the relation of single packets to particular later characteristics—gave rise to a general doctrine, a philosophy, of heredity and development—a doctrine which has had and still has a very great influence on general views of life. It is to this doctrine that the prevailing ideas as to the relation of heredity and environment, as to the relative powerlessness of environment, are due. But it has turned out to be a completely mistaken one. This fact has not come to general consciousness: the doctrine continues to be a source of mystification and error. Its complete disappearance would mean a very great advance in the understanding of life.

From the fact that the "unit characters" changed when a single gene changed, it was concluded that in some ill-defined way, each characteristic was "represented" or in some way condensed and contained, in one particular gene. There was one gene for eye color, another for stature, another for feeble-mindedness, another for normal-mindedness, and so on. Every individual therefore came into the world with his characters fixed and determined. His whole outfit of characteristics was provided for him at the start; what he should be was preordained; predestination, in the present world, was an actual fact. Environment might prevent or permit the hereditary characters to develop; it could do nothing more. Heredity was everything, environment almost nothing. This doctrine of the all-might of inheritance is still proclaimed by the popularizers of biological science.

But this theory of representative particles is gone, clean gone. Advance in the knowledge of genetics has demonstrated its falsity. Its prevalence was an illustration of the adage that a little knowledge is a dangerous thing. The doctrine is dead—though as yet, like the decapitated turtle, it is not sensible of it. It is not true that particular characteristics are in any sense represented or condensed or contained in particular unit genes. Neither eye color nor tallness nor feeble-mindedness, nor any other characteristic, is a unit character in any such sense. There is indeed no such thing as a "unit character," and it would be a step in advance if that expression should disappear.

What recent investigation has shown is this: the chemicals that were in the original packages derived from the parents—the genes—interact, in complex ways, for long periods; and every later characteristic is a long-deferred and indirect product of this interaction. Into the production of any characteristic has gone the activity of hundreds of the genes, if not of all of them; and many intermediate products occur before the final one is reached. In the fruit fly at least 50 genes are known to work together to produce so simple a feature as the red color of the eye; hundreds are required to produce

normal straight wing, and so of all other characteristics. And each of the cooperating packets is necessary; if any one of the fifty is altered, the red color of the eye is not produced.

And this is what gave rise to the idea of unit characters represented by particular genes. For suppose that one parent has all the fifty packets necessary to produce the red eye, while the other has but forty-nine of them, the fiftieth containing some substance that will not work in producing red. Then this parent will not have a red eye, but perhaps a white one, although it differs from the other in but one gene. When these parents produce descendants, the red and white eyes follow in heredity the distribution of that single pair of genes of which one is altered: wherever the altered gene alone goes appears a white eye; wherever the unaltered one of the pair, a red eye. So the red color and the white color, inherited according to the Mendelian law, were called unit characters; each was supposed due to a single gene.

But actually, fifty or more genes are required to produce either, as is discovered when some other one of the fifty is changed off for an altered one. Then, although the first pair of genes is now unaltered, still the red eye does not appear. Now the eye color follows the distribution of another pair of genes.

By successively altering genes of different pairs, or by altering genes of two or more pairs in the same parents, certain general relations of the greatest significance are discovered—relations which are commonly ignored. A certain characteristic, such as the red color, may, with a given pair of parents, follow a given gene, being inherited according to a particular rule—say the "typical Mendelian" rule. In other parents it follows a different gene, and is inherited in a different way—perhaps as a "sex-linked" character. There are fifty or more separate and independent ways by which the red character can be altered, and each yields a somewhat different rule of inheritance. Or in the same individual two or more of the genes affecting color may be altered; then the color is no longer inherited as a "unit character;" its inheritance is now of the "multiple factor" type. In some cases it will follow the rules for two-factor cases; in others for three, and so on indefinitely, until the inheritance may not be distinguished from the "blending" type. Such cases are typical. The fact that in an observed instance a characteristic is inherited as a "unit character" does not show that in other cases it will be so inherited. If a characteristic is observed in a given case to be inherited as a sex-linked character, we can not be certain that it will be sex-linked in other cases. If it is recessive in some stocks, it may be dominant in others. Feeblemindedness appears to be inherited at times as a "unit character"; although nothing can be more certain than that hundreds of genes

are required to make a mind—even a feeble mind. It is not surprising that absence or alteration of some one necessary chemical should leave the mind imperfect; this is all that is shown by "unit character" inheritance. Doubtless feebleness of mind is produced in hundreds of different ways—some sorts heritable according to one set of rules, others according to other sets of rules. Color blindness in man appears in some cases to behave as a sex-linked character: this does not make it certain that in other cases it will do so. It is a general truth that, even though we have worked out the precise method of inheritance of a characteristic in a given stock, we can not be certain that this same characteristic will be inherited in that way in another stock. It all depends on which particular one or more of the hundreds of genes on which the character depends is diverse in the two parents. Heredity is not the simple, hard-and-fast thing that old-fashioned Mendelism represented it.

Further, more attentive observation has revealed that any single one of the genes affects, not one characteristic only, but many, probably the entire body. The idea of representative hereditary units, each standing for a single later characteristic, is exploded: it should be cleared completely out of the mind.

The genes then are simply chemicals that enter into a great number of complex reactions, the final upshot of which is to produce the completed body. The characters of the adult are no more present in the germ cells than is an automobile in the metallic ores out of which it is ultimately manufactured. To get the complete, normally acting organism, the proper materials are essential; but equally essential is it that they should interact properly with each other and with other things. *And the way they interact and what they produce depends on the conditions.*

This is shown to be true both through observation of the processes of interaction, in development; and through experimentation with diverse conditions. Under the microscope the set of genes—the chromosomes of the egg—are seen to go promptly to work. They suck up a quantity of material from the surrounding cytoplasm, becoming balloon-like. They transform this chemically, then give it off again into the cell body, visibly changed into something new. Diverse new substances thus formed move into different regions of the egg. By cell division some of the newly manufactured substances are passed into one cell, others into another. Thus the cells become diverse; the different structures of the body are being made. This is repeated in each cell generation, the chromosomes by interaction with the cytoplasm changing the substance of the cells, until finally nerve, muscle, bone, gland and other tissues result. But in all this interaction of the chromosomes to produce new cytoplasmic materials, the chromosomal materials—the genes

—are not themselves used up. Always a reserve portion of each chromosomal substance is saved, so that none of them are lost and their number does not decrease. And at each cell division every reserve packet is divided, half of it going to each of the two cells, where it grows to full size. So every cell of the body continues to contain the entire set of the parental chemicals, just as the egg did. The differences between the diverse cells of the body are therefore not in these substances—not in the genes they contain—but in the remaining part of the cells, the cytoplasm; these differentiations have been produced by the interaction of the genes with the cytoplasm. It is in this way that the complex adult body, with its typical pattern of structures, is produced.

In producing these structures, the genes interact, not only with each other, with the cytoplasm, with the oxygen from the surrounding medium, and with the food substances in the cytoplasm: but also, what is most striking and important, with products from the chemical processes in neighboring cells. Necessarily, then, this complicated interaction depends upon many conditions, a dependence that becomes manifest as methods of experimentation become precise. The process of development shows itself not to be stereotyped, as at first appears to be the case; it varies with changes in conditions. What any given cell shall produce, what any part of the body shall become, what the body as a whole shall become—depends not alone on what it contains—its "heredity"—but also on its relation to many other conditions; on its environment.

This is well shown in the development of our close relatives, the amphibia. The frog or salamander begins as a single cell, which divides into two. Usually one of these two produces the right half of the body, the other the left half. But this depends on the relation of the two cells to one another; separate them, and each produces an entire animal instead of half a one. Somewhat later in development the young salamander has become a sphere of many small cells, differing in different regions. Under usual conditions it is possible to predict what later structure each cell, each region of the sphere, will produce. The cells that will produce brain, eye, ear, spinal cord, skin, can be pointed out. The predicted process occurs with such regularity as to appear stereotyped.

But study shows that this is because the effective environment is usually the same for any given cell. What any cell shall become depends in fact on the conditions surrounding it: on its relation to the other cells. Development, it turns out, is a continual process of adjustment to environment. The recent brilliant work of Spemann shows that at a certain point in the developing mass of small cells (just in front of the blastopore) there begins a differentiating influence, whose further nature we do not know. This creeps from

cell to cell, forwards and sideways, determining the type of chemical processes that shall occur in each cell, in such a way as to fit and conform the structures produced by that cell to those produced by the cell differentiated just before it. In this way the whole mass of cells diversifies into the pattern of the later structures. Here the cells differentiate into spinal cord, next into medulla, next into midbrain, here at the side into eye, here into ear; still farther on into skin. But if before this has happened the disk of cells is cut off and turned sideways, or completely around, the differentiating and adjusting influence creeps through it from the same point as before, but now in a different or reversed direction, so far as the cells are concerned. The cells that were to have formed skin produce spinal cord; those that would have produced eyes may form midbrain, or skin or ear, depending on just how they are placed with reference to the spreading differentiating influence; and so of the others. Or, transplant a small piece of prospective skin to the center of the eye-producing region; it now transforms into eye instead of into skin; transplant a prospective ear to another region, and it becomes skin or spinal cord, as its place in the pattern requires. It is proved that any particular cell may become part of any one of these structures, depending on its relation to the other cells, its relation to the "pattern." There comes a time after the wave of differentiation has gone over them, when they can no longer be altered; their fate has been accomplished. But until then development is adjustment to the conditions. What part of the body a cell shall produce is not determined alone by its genes, by what it contains, but equally by the conditions surrounding it.

In later stages we know something of the nature of the cell products which help determine what other parts of the body shall become. There are a vast number of such intermediate products, necessarily produced before the adult structures can be made; some of them are the internal secretions, hormones or endocrine products which are now the reigning sensation in biology. Their production, their distribution, their action and the consequent method of development of the organism are subject in high degree to change by the surrounding conditions.

Not only what the cell within the body shall become, but what the organism as a whole shall become, is determined not alone by the hereditary materials it contains, but also by the conditions under which those materials operate. Under diverse conditions the same set of genes will produce very diverse results. It is not true that a given set of genes must produce just one set of characters and no other. It is not true that because an individual inherits the basis for a set of characteristics that he must have those characteristics. In other words, it is not necessary to have a certain char-

acteristic merely because one inherits it. It is not true that what an organism shall become is determined, foreordained, when he gets his supply of chemicals or genes in the germ cells, as the popular writers on eugenics would have us believe. The same set of genes may produce many different results, depending on the conditions under which it operates. True it is that there are limits to this; that from one set of genes under a given environment may come a result that no environment can produce from another set. But this is a matter of limitation, not of fixed and final determination; it leaves open many alternative paths. Every individual has many sets of "innate" or "hereditary" characters; the conditions under which he develops determine which set he shall bring forth. So in man, the characteristics of an educated, cultured person are as much his inherited characteristics as are any that he has.

These sweeping statements are substantiated by precisely known facts in many organisms. In that animal whose heredity is better known than is that of any other organism, the fruit fly, individuals occur with hereditary abnormalities. The abdomen is irregular, deformed; the joints between the segments are imperfect. This is sharply inherited as a sex-linked character, so that it is known to be due to a peculiarity of one of the genes in the x-chromosome. If the father has this abnormality, all his daughters inherit it, but none of his sons do so. The daughters hand it on to half their sons and half their daughters, and so on.

But the fruit flies in the laboratory usually live in moist air; this inheritance appears under those conditions. If they are hatched and live under dry conditions the abnormality doesn't appear—even in those daughters which indubitably inherit it. Clearly, it is not necessary to have a characteristic merely because one inherits it. Or more properly, characteristics are not inherited at all; what one inherits is certain material that under certain conditions will produce a particular characteristic; if those conditions are not supplied, some other characteristic is produced.

Similarly, some of the fruit flies inherit, in the usual Mendelian manner, an inconvenient tendency to produce supernumerary legs. But if those inheriting this are kept properly warmed, they do not produce these undesirable appendages. In the cold, only those individuals acquire the extra legs that have inherited the gene to which such are due; but even they need not do so, if conditions are right. In the same animal, some individuals have fewer facets in the compound eye than do others. The number of facets is found to be hereditary, in the sense that under the same conditions parents with few facets produce offspring with few facets, in the Mendelian manner. But the number also depends on the environment; individuals with the same inheritance show different numbers of facets,

depending on the temperature at which they develop. If the individual A has a certain number of facets, while B and C have a different number, the same in both, it may be found that the difference between A and B is due to inheritance, while the same difference between A and C is due to environment. Such facts are typical; differences due in one case to heredity may be due in another to environment. There is no characteristic distinction between hereditary diversities and environmental diversities; whether a given instance belongs in one or the other category can be determined only by experimental analysis.

Other known cases illustrate the effect of the environment in altering the totality of the organism; its entire personality, as it were. Many years ago there was discovered in Mexico a salamander that lives throughout its life in water; has a heavy, broad body, a tail flattened for swimming and external gills. In this condition it becomes mature, lays its eggs in the water; produces young that inherit its characteristics and finally dies. This continues for generation after generation. A number of these axolotls were kept for years in the zoological garden at Paris; they showed the inherited characteristics above set forth. Breeding experiments on these animals would show these characteristics to be inherited in the usual Mendelian manner.

But after years in which these were the only inherited characteristics that they were known to possess, certain different environmental conditions were brought into action, and thereupon, to the astonishment of the observers, the axolotls developed a new set of inherited characteristics, a new and diverse personality. The external gills disappeared, the body became smaller, slender and of a very different shape, the animals came out on the land and remained there, breathing air. They now became mature in this amblystoma condition, laid eggs, and produced offspring—which again, under these conditions, developed into land animals of the same sort; and this too may continue for generation after generation. The inherited characteristics are now these land characters; these are, in detail, inherited in the typical Mendelian manner.

Here we have two extremely different sets of inherited characters; which one shall appear is determined by the environment under which the organism develops. Both sets are hereditary characters; both sets are environmental characters. Any character requires for its production both an adequate stock of hereditary chemicals and an environment adequate for its production through proper interaction of these chemicals with each other and with other things.

Beyond all other organisms, man is characterized by the possession of many sets of inherited characteristics; the decision as to

which shall be produced depending on the environment. The axolotl may be compared to an uneducated man, the amblystoma to an educated one. The educated man has characteristics very diverse from those he would possess if uneducated. We say, when we think of this fact, that these are acquired characters, environmental characters, due to education. This is correct; but there is a tendency to go farther and say that these are not inherited characters, which is a mistake. The characteristics of the educated man are his native, inherited characters, just as truly as are any that he has. For all his characteristics depend on the conditions under which he develops, and would be diverse under different conditions, just as is true of the characteristics that develop under education. And the characters developed under education depend upon the hereditary materials derived from his parents, changing as these materials are altered, just as do all others. "Hereditary" has no consistent meaning other than this.[1]

Why it seems paradoxical to call the characteristics developed under education inherited, while we make no difficulty in thus designating the color of the eyes and the stature, lies in certain practical difficulties, not in any difference of principle. In the group of organisms to which man belongs there is an early period in which it is practically difficult to change effectively the conditions under which the organism develops, because it is enclosed within the mother's body, or within a resistant egg shell. So we have gotten accustomed to calling inherited those characteristics which are determined before it leaves its mother's body or the egg, while those determined later are called acquired characters. But this is an artificial distinction, based on practical considerations. In many organisms there is no such distinction into two periods; in them it is possible to alter the conditions at any period, even the earliest. And when this is done it is found that *all* the characters depend on the conditions; that such fundamental characters as the number of eyes an animal has or the position of the eyes in the body may be altered. In fish, for example, two eyes, one at each side of the middle line, form as distinctly an inherited characteristic as in man, yet fish can be subjected so early to changed conditions (as Stockard and others show) that the animal has a single median eye instead of two lateral ones; and many other equally

[1] Did not painful experience demonstrate the contrary, it would appear obviously unnecessary to emphasize that nothing in this paper has any bearing on the traditional doctrine of the "inheritance of acquired characters." This doctrine asserts, in effect, that the production of a characteristic under the influence of some specific peculiarity of the environment so changes the genes that in a later generation they produce this characteristic even in an environment that lacks the peculiarity which was originally necessary; a most doubtful thesis.

striking changes are producible by changes in the chemical environment. If the fish lived continuously in these conditions they would regularly inherit a single median eye; the two lateral eyes would be looked upon as a rare abnormality, produced by special conditions and not inherited. In truth, all characters are as certainly due to the conditions of development as to the materials of the germ cells.

If there were not practical difficulties in the way, similar fundamental changes of structure could be made in man or any of the higher animals. In these higher creatures, a time comes, before development stops, in which it *is* possible to change the conditions; that is, after what we call birth. And then it is found that changing the conditions does change the characteristics that later develop —exactly as the characteristics of the fish are changed by changing the conditions. We call this process education; if we could give the same education for many generations to a number of different human families, we should find that the characteristics resulting from education are inherited, just as are color of the eyes and form of the head; that they follow Mendelian rules, as do physical characters. Every creature has many inheritances; which one shall be realized depending on the conditions under which it develops; but man is the creature that has the greatest number of possible heritages. Or, more accurately, men and other organisms do not inherit their characteristics at all. What their parents leave them are certain packets of chemicals which under one set of conditions produce one set of characters, under other conditions produce other sets. In man, the number of diverse sets that may thus be produced is very great; although it is of course not unlimited. But what the limitations are can not be stated from general biological principles or from what we know of any other organisms; they can be discovered only by concrete studies of man himself.

Adequate recognition of these facts and principles, which appear fully established by the advance of genetics, would greatly alter some of the current discussions and attitudes on the relation of biological science to human affairs. The biologist is pained to find that the medical man resists the introduction of the concept of heredity into the domain of disease. This is because of the current fallacy that what is hereditary is certain, fixed, unchangeable. Very properly the medical man rejects that, in its application to disease. But with the recognition that to assert that a thing is hereditary signifies merely that the organism has received such a constitution as to produce it under given conditions, all such ground of objection vanishes. This does not deprive of significance recognition of the part played by heredity in medicine. The individual who may produce an inherited defect under certain condi-

tions need not produce it under others. Some individuals receive a constitution which resists disease under conditions in which others succumb to it. Some respond in one way to particular therapeutic agents, others in another way, depending on their hereditary genes. It is only against what Davenport has characterized as purely impersonal medicine that the implications of genetic science lie.

The same fallacy reappears in discussion of immigration problems. The recent immigrants show certain proportions of defective and diseased persons; and we are informed that "these deficiencies are unchangeable and heredity will pass them on to future generations." There is no warrant in the science of genetics for such a statement; under new conditions they may not appear. It is particularly in connection with racial questions in man that there has been a great throwing about of false biology. Heredity is stressed as all powerful; environment as almost powerless: a vicious fallacy, not supported by the results of investigation. We are warned not to admit to America certain peoples now differing from ourselves, on the basis of the resounding assertion that biology informs us that the environment can bring out nothing whatever but the hereditary characters. Such an assertion is perfectly empty and idle; if true it is merely by definition: anything that the environment brings out *is* hereditary, if the word hereditary has any meaning. But from this we learn nothing whatever as to what a new environment will bring out. It may bring out characteristics that have never before appeared in that race. What the race will show under the new environment can not be deduced from general biological principles. Only study of the race itself and its manner of reaction to diverse environments can give us light on this matter.

All characteristics, then, are hereditary, and all are environmental. Does not this deprive the study of the distinctive parts played by the two of all sense and value? It does not. It is of the greatest importance to know in what different ways diverse stocks respond to effectively the same environment; and how these diversities are perpetuated; what limitations the original constitution puts on what the environment can bring out; this is the study of heredity. It is equally important to know what differences appear among stock of the same original constitution under diverse environments; how great the possibilities of environmental action are with a given stock. In man, where practically every individual represents a different stock and a different environment, the matter is not one for sweeping generalizations based on general biological principles. The concepts of the hereditary and the environmental can not be employed in the absolute way now practiced; but they can be used with entire precision if they are applied, not to characteristics-in-themselves, but to the diversities between different par-

ticular concrete cases. Though stature is always dependent on both heredity and environment, the difference in stature between Mr. Jones and Mr. Smith may be purely a matter of heredity; the difference between the same Mr. Jones and Mr. Brown may be purely a matter of environment. If there is clarity as to what comparison is made, there need be no ambiguity as to what is due to heredity, what to environment.

By statistical extension, such comparison may be made for large classes. But it is essential here as elsewhere to keep in mind that we are dealing with comparisons between concrete cases, not with propositions of absolute validity. Are the differences between men due more to heredity or to environment? If we compare ourselves with our ancestors of 10,000 years ago, they are due mainly to environment— if it is correct, as generally admitted, that the fundamental constitution of the stock has not appreciably changed since that time. If the comparison is of ourselves with the Bushmen of South Africa, possibly the differences are mainly due to heredity. If the comparison is between the diverse races of Europe, or between the individual citizens of the United States, the answer is to be obtained only from a much greater amount of precise study, with critical statistical treatment, than has yet been made; and there is reason to think that it would signify little when reached, since it would be merely an average of a very great number of individual comparisons, many falling to one alternative, many to the other. Certainly the answer is not to be deduced from any alleged biological principle that the characteristics of organisms are due to heredity and not to environment.

THE ALCHEMIST[1]

By Dr. PAUL D. FOOTE

BUREAU OF STANDARDS

THE volumes on alchemy in our large libraries may be counted by the hundreds. Innumerable tracts and treatises filled with the most incomprehensible nonsense ever written have appeared in Spanish, Italian, German, Dutch, English, Arabic, Persian and Latin. The name alchemy is probably of Arabic origin, dating from the eighth century, the prefix "al" being Arabic for "the" and "chema," meaning to hide. Alchemy accordingly denotes "the hidden science." The prefix *al* occurs in many of our scientific words; alcohol, *the* burning liquid; alkali, *the* acrid substance; algebra, *the* reunion, and many others.

The scope of alchemy is a disputed question. According to the transcendental theory, it did not purport to be a science at all, but rather was concerned with man's soul. Its object was the perfection, not of material substances, but of man in the spiritual sense, a branch of mysticism in which transmutation was symbolical of the salvation of humanity.

However, most of the alchemists themselves were of the opinion that the primary object of their endeavors should be confined to the production of gold. These were the real alchemists in which we are now interested. Of such there were naturally two types. There was the knavish, corrupt alchemist, who, as Rodwell[2] says, had brains enough to perceive that his search was futile and utilized his wits to dupe more credulous people, wheedling their fortunes out of them on pretense of returning it tenfold. Modernized, these men are our successful oil-stock promoters. They abounded during the Middle Ages and became immensely wealthy by such shallow tricks as the secretion of a piece of real gold in the crucible in which the pretended transformation was taking place.

Then there were the alchemists proper, ardent, persevering

[1] Published by permission of the Director of the Bureau of Standards, Department of Commerce.

[2] Rodwell—"The Birth of Chemistry," MacMillan, 1874. This book and Redgrove's "Ancient and Modern Alchemy," Rider and Son, 1911 and 1923, contain excellent historical summaries. Several of the alchemical illustrations in the present paper were taken from these two books rather than from the original sources. Rodwell's work is especially interesting because it was written nearly fifty years ago when the atom was considered the ultimate unit; when the subject of alchemy stood in extreme disrepute.

FIG. 1. HERMES, FROM THE TEMPLE OF PSELCIS

The alchemical writers of the middle ages claimed every great man and deity of antiquity as of their number, although alchemy was practically unknown prior to the eighth century. We derive our expression "hermetically sealed" from the alchemical use of the name Hermes.

workers, who believed heart and soul that gold could be made and that by long search or diligent study of the unintelligible works of their predecessors they could discover the philosopher's stone. Poor misguided wretches—they have now become chemists, for the science, or rather art, of chemistry owes its origin to the labors of these honest men.

Honest?—only in the relativity sense, however! One needs merely to read a dozen volumes or so of their testimonials to realize that the world is growing better. For example, Magnus, of the thirteenth century, could instantly transform a winter's day into glowing summer, an accomplishment fully described by many writ-

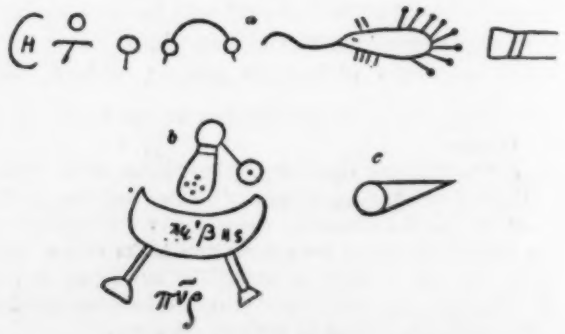
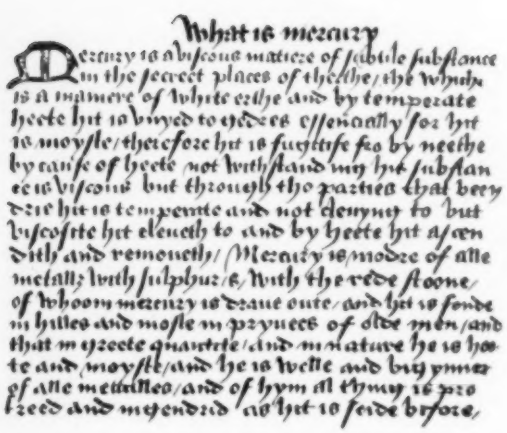


FIG. 2. AN ALEMBIC AND SYMBOLS FROM A GREEK MANUSCRIPT ON ALCHEMY


What is mercury

Mercury is a viscous matter of subtle substance in the secret places of the earth, the which is a manner of white earth and by temperate heete hit is moved to werkes essentially for hit is moysle, therefore hit is fugitife for by neethe by cause of heete not withstanding hit substance is viscous but through the practice that bery doth hit is tempered and not denyed but viscosite hit eleueth to and by heete hit ascendith and remoueth. Mercury is modre of alle metall; with sulphur & with the rede stoone of whoom mercury is drawe oute and hit is fonde in hilles and mosle in prynces of olde men and that in greete quantite and in nature he is hote and moysle and he is welle and buyxmer of alle metalles and of hym al thyng is pro breed and engendrid as hit is seide before.

Fig. 3. English Manuscript on Alchemy dating from the Fifteenth Century

ers and witnesses. His pupil, Thomas Aquinas, constructed a bronze statue which Magnus animated with his elixir of life. This statue was useful as a domestic servant, but was very noisy and talkative. Finally, Aquinas was forced to punish it severely with a hammer in order to continue his studies in quiet. Lulli, a contemporary, converted 50,000 pounds of base metal into the purest of gold and was employed by one of the Kings Edward to replenish the exchequer. This he did to the extent of 30 millions of dollars in synthetic gold bullion. Henry VI granted patents to alchemists on the processes involved in the manufacture of philosopher's stones. In 1404 the making of gold and silver was forbidden by

Fig. 4. An Alchemist Hermetically sealing a Flask containing the Elixir of Life

Note the symbol for the sun, representing gold.

FIG. 5. AN ALCHEMIST'S METHOD FOR EXPLAINING CHEMICAL REACTIONS

Note the symbols for gold (sun), silver (moon) and mercury. The lion devouring the snake represents an acid dissolving a salt.

Act of Parliament. To such dangerous proportions had the industry developed that the welfare of the state was threatened.

There is no doubt that the true alchemists, like the modern scientist, were much overworked individuals. Paracelsus affirms that "they diligently follow their labors, sweating whole days and nights by their furnaces. They do not spend their time abroad for recreation but take delight in their laboratory. They wear leather garments with a pouch, and an apron wherewith they wipe their hands. They put their fingers amongst coals, into clay and filth, not into gold rings. They are sooty and black like smiths and colliers and do not pride themselves upon clean and beautiful faces."

Let us peep into the laboratory—"a gloomy dimly lighted place full of strange vessels and furnaces, melting pots, spheres and portions of skeletons hanging from the ceiling; the floor littered with stone bottles, alembics, great parchment books covered with hieroglyphics; the bellows with its motto Spira Spera (breathe and hope); the hour glass, the astrolabe, and over all cobwebs, dust and ashes. The walls are covered with various aphorisms of the brotherhood; legends and memorials in many tongues. Look at Faust as depicted by Rembrandt for a truly alchemical interior."

Alchemy as practiced during the middle ages was the logical outgrowth of accepted philosophical thinking, which dated from the fifteenth century B. C. and was given new impulse by Aristotle in the fourth century B. C. This theory postulated four elements, earth, fire, air and water. Gradually, the terms assumed a broader meaning. All incandescent objects, lightning, electrical sparks, were represented as fire. Smoke, steam, vapors and gases were called air. Water included all liquids, blood, milk, and later solu-

tions and acids, terminology now surviving in aqua fortis, aqua regia, eau de vie. Any solid was an earth, and to-day we have the *earth metals* and the *rare earths* as a result of this early usage. The general idea of four elements was not disproven until a century and a half ago, when air was found to be a mixture of two (later several) gases, fire the result of intense chemical action and earth a mixture of many elementary materials.

With these hypotheses, transmutation was experimentally demonstrable. Fire converts water into steam or air. The alchemists therefore reasoned, plausibly enough, if water can become air why may not one metal, which was supposed to be compounded of these elements in certain proportions, be changed into another metal compounded of the same elements in a different proportion. Admitting the possibility of the process, it is not strange that men attempted to produce gold. Gold has been valued since the earliest antiquity on account of its peculiar color, its luster, its unalterability in air, and especially its rarity as compared with other commodities. For its procurement, the lives of millions of men have been sacrificed in battle, in the forever distant past, praise Heaven!

It is useless to describe the methods which the alchemist employed in carrying out his prolonged attempts at transmutation. The intricate processes were subdivided into twelve groups technically known as calcination, dissolution, separation, conjunction, putrefaction, congelation, cibation, sublimation, fermentation, exaltation, multiplication and projection. A misstep at any stage in the development was fatal to the process and all the fruit of months of toil was lost in a single moment. The modern chemist or physi-

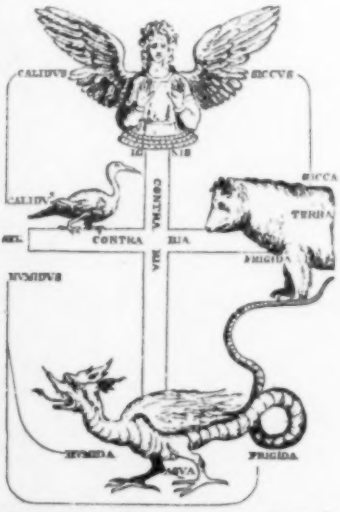


FIG. 6. AN ALCHEMICAL REPRESENTATION OF TRANSMUTATION

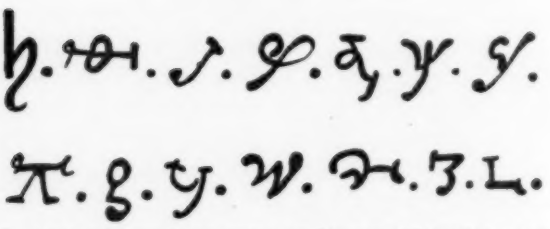


FIG. 7. SYMBOLS FOR LEAD FROM AN ITALIAN MANUSCRIPT OF THE SEVENTEENTH CENTURY

cist carries through no more elaborate experiments than those of the early alchemists.

The mystical language which these savants adopted was intended to prevent the vulgar from acquiring the results of their long-continued labors. This obscurity led to multiplication of symbols which were nearly as voluminous as those employed in astrology. In a single Italian manuscript the element mercury is represented by 22 different symbols and by 33 different names.

To illustrate how utterly nonsensical and unintelligible alchemical language could be and generally was, we quote from Paracelsus, one of the greatest alchemists of the sixteenth century:

> The life of metals is a secret fatness; . . . of salts, the spirit of aqua-fortis; . . . of pearls, their splendor; of marcasites and antimony, a tinging metalline spirit; . . . of arsenics, a mineral and coagulated poison. The life of all men is nothing else but an astral balsam, a balsamic impression, and a celestial invisible fire, an included air and a tinging spirit of salt. I can not name it more plainly although it is set out by many names.[3]

Figs. 1 to 7 show several typical illustrations from the early alchemical literature. The interpretation of these fanciful drawings is difficult and has proven a matter of some discussion and variance of opinion. Figs. 5 and 6 are more directly related to the transcendental or mystic aspect of the art of alchemy. Ancient books on alchemy are literally filled with allegorical pictures of this character, many of which are in color and artistically decorated.

MODERN ALCHEMY

Let us pass over a period of two hundred years and consider the subject of modern alchemy. The new developments are due to the great strides made during the past twenty years in our knowledge of atomic structure. Fig. 8 shows a photomicrograph of a copper ingot magnified 250 times. This beautiful structure is also characteristic of gold. Such photomicrographs enable the metallurgist

[3] Paracelsus, De Natura Rerum.

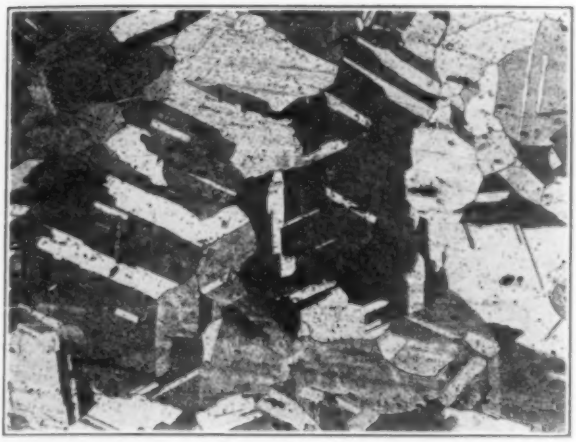


FIG. 8. PHOTOMICROGRAPH OF COPPER, MAGNIFICATION × 250
(RAWDON AND LORENTZ)
Gold presents a similar crystal structure.

to determine whether or not a metal or alloy has the proper constitution or has been given a specified heat treatment.

Now by the aid of a supermicroscope we shall magnify a sample of gold thirty million diameters, Fig. 9. We see a space-lattice arrangement of solid spheres, each sphere an atom of the precious metal. Elastic vibration of these spheres about their positions of equilibrium accounts in a qualitative way for the specific heat of gold. The entire structure of the kinetic theory owes its success to the fact that atoms, magnified as shown, by virtue of their electric forces, do approximate hard spheres or billiard balls, especially in gases where their separation is many times that here illustrated.

We shall now use an objective of higher power and magnify a single atom 240 million times, Fig. 10. This is an atom of copper. We have a planetary system consisting of a positively charged sun

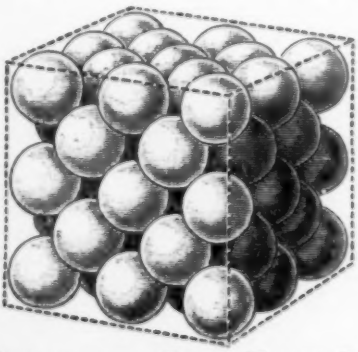


FIG. 9. GOLD MAGNIFIED THIRTY MILLION DIAMETERS
Each sphere represents an atom.

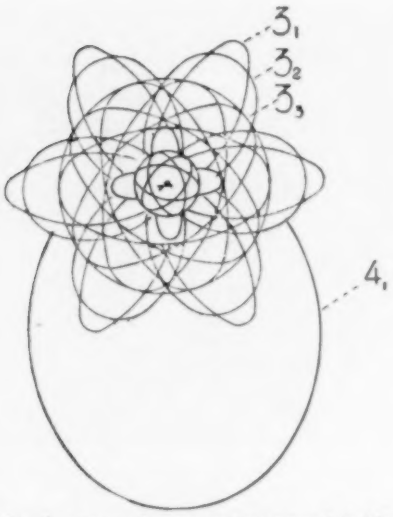


FIG. 10. AN ATOM OF COPPER MAGNIFIED 240 MILLION TIMES

There are 29 elliptical orbits each one occupied by a single electron. Gold has a similar general appearance but its inner structure is much more complicated by the presence of 50 additional orbits. The original drawing and model are due to Bohr.

surrounded by revolving planets or electrons. Each elliptical orbit is occupied by a single electron. Copper possesses a nucleus carrying a positive charge of 29 units and a planetary system of 29 revolving electrons. Gold has a positive nucleus of 79 units with 79 electrons, each revolving in its own elliptical orbit. Nearly all the mass of any atom is contained within the nucleus. The surrounding electrons contribute practically nothing to the total atomic mass, and yet the nucleus is so small as to be scarcely representable on this scale of magnification. The electrons revolving in the outer elliptical orbits are responsible for the ordinary spectrum of an element and for its chemical and physical behavior; the electrons on the inner orbits give rise to x-ray spectra. The net positive charge on the nucleus is numerically equal to the atomic number of an element, or to the ordinal number characterizing its position in the Periodic Table; 1 for hydrogen, 2 for helium, 10 for neon, 79 for gold and 92 for uranium.

The nucleus also has a very complicated structure. The sun in the atomic solar system is itself a planetary system built up of hydrogen suns, helium suns and electrons. Our microscope has not sufficient resolving power to clearly indicate the configurations which these three units assume when grouped together to form the nucleus of a heavy atom such as gold. Fig. 11 shows the sun of the helium atom magnified four thousand billion diameters. It con-

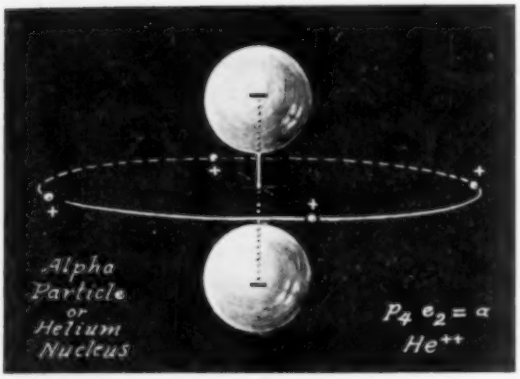


FIG. 11. THE SUN OR NUCLEUS OF A HELIUM ATOM MAGNIFIED 4,000 BILLION DIAMETERS (Drawn by H. D. Hubbard)

sists of four minute hydrogen nuclei and two relatively large electrons. Now the sun in an atom of gold may have 49 of these helium suns, one extra hydrogen sun and 20 electrons, all packed in the space of 30 billionth billionth billionth billionth of a cubic centimeter. Alchemy is concerned with reactions involving the disintegration of these minute nuclear suns.

Nature has always performed transmutations of the elements, but these were not noticed by scientists until 1896, when the discovery of radioactivity was made. Since then we have isolated about 40 radioactive atomic species each with well-known physical and chemical properties and each with a definite and characteristic kind of radioactivity. All in this group have atomic weights lying between about 200 and 238, and hence are our heaviest elements.

One of these elements is radium, which chemically and physically resembles barium and which belongs to the second Group of the Periodic Table. This atom possesses a planetary system of 88 electrons revolving about a complicated nucleus having a net positive charge of 88 units, as shown in Fig. 12. The nucleus is located at the center of the configuration, but is too small to appear in the figure. Now every once in a while a radium atom spontaneously ejects a particle from its nuclear structure. This particle, which is known as an α-ray, is emitted with a velocity of about 10,000 miles per second, or twenty thousand times greater than that of the swiftest rifle bullet. Mass for mass, its energy of motion is four hundred million times greater than that of the bullet.

The atom of the metal radium which emitted this α-particle is no longer radium.[4] It has been transmuted into an atom of a gas

[4] The "mortality" of radium atoms is 4 "deaths" per 10,000 per year; that of human beings is around 140.

called niton or radium emanation, belonging to the family of rare gases, helium, neon, argon, etc. Niton consists of a nuclear structure containing a net positive charge of 86 units surrounded by 86 planetary electrons. The schematic representation of these orbits is similar to that of Fig. 12 except the two orbits extending to the extreme upper right and left hand corners of the illustration are absent. The real difference between neon and radium, however, is due to the transformation which has taken place in the nuclear structure. One may remove the two protruding orbits (the valence electrons) of radium without producing niton. This is possible in a simple chemical reaction.

The atoms of the gas niton similarly explode once in a while and each atom emits an α-particle from its nucleus with a definite velocity, while the parent gaseous atom is transmuted into an atom of a new material, a solid, having the chemical properties of an element in the sixth group of the Periodic Table. And so the process continues as will appear later.

If these α-particles are allowed to strike a photographic plate, fogging is produced. If they fall on a fluorescent screen, such as zinc sulphide, they give rise to luminosity or scintillations, an effect which may be seen in the spinthariscope. If they pass through a gas they are capable of rendering the gas electrically conducting. It is because of these properties that the α-particle may be easily studied. In this way we have determined the following facts:

(1) By observing the deflection of the α-particles in electric and magnetic fields we learn that the particle carries a positive charge, and the velocity with which the particle is projected is characteristic of the parent atom.

(2) By counting the scintillations produced by a definite amount of radioactive material upon a screen of a definite size we

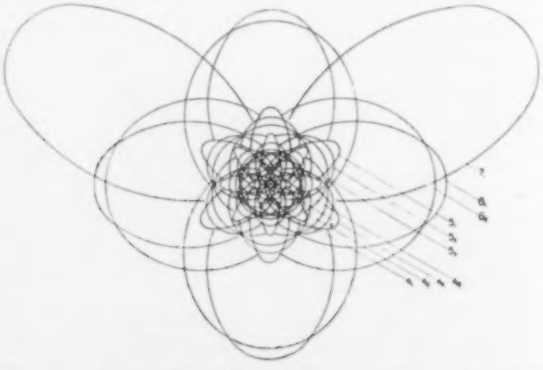


FIG. 12. AN ATOM OF RADIUM MAGNIFIED 140 MILLION DIAMETERS
There are 88 elliptical orbits each one occupied by a single electron.
Original drawing and model are due to Bohr.

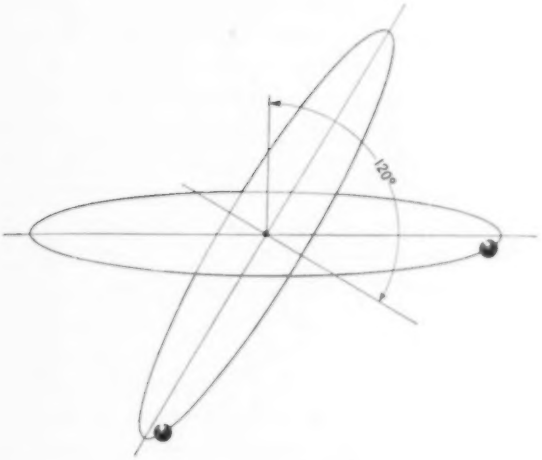


FIG. 13. KEMBLE-BOHR MODEL FOR THE HELIUM ATOM MAGNIFIED ONE BILLION DIAMETERS

The small dot in the center is the α-particle of which Fig. 11 is a magnified picture.

are able to determine the number of α-particles which the material emits per second.

(3) By collecting these particles in a suitable electrical apparatus we may measure their total charge and hence the charge on a single α-particle. This is found to be two units of positive electricity.

(4) Knowing the charge, it is possible to determine the mass of the α-particle by measuring its deflection in electric and magnetic fields. The mass so observed is 4 relative to oxygen 16. That is, the mass of an α-particle is the same as the mass of a helium atom.

(5) The α-particle is capable of passing through very thin glass. If a quantity of niton gas is compressed and sealed in a thin glass bulb and this bulb is placed inside a larger evacuated and sealed bulb, having heavy walls, it is found that the pressure in the outer bulb gradually increases as the α-particles penetrate into the space. After a few days enough gas accumulates so that an electrical discharge may be passed through it. The spectrum reveals the newly formed gas as pure helium. Hence not only does the α-particle have the same mass as a helium atom, but it *is* a helium atom, from which the two outer planetary electrons have been removed. The α-particle or helium nucleus in the outer bulb immediately picks up two electrons and becomes an ordinary helium atom as shown in

Fig. 13. The small dot in the center is the α-particle or helium nucleus of which Fig. 11 is a magnified picture.

The atomic weight of radium is 226. An atom of radium emits an atom of helium of weight 4 and is transmuted into an atom of the rare gas niton of atomic weight 222. This gas emits helium and is transmuted into RaA, a solid weighing four units less, namely, 218; RaA emits helium and is transmuted into RaB of weight 214. RaB does not emit helium, yet it also is transmuted into a new element called RaC, this time however without change in weight. Experiments similar to those performed with α-rays show that when RaB is transmuted into RaC, an electron is emitted with a velocity three quarters that of light. Since the mass of an electron is inappreciable compared to that of the nucleus of a heavy atom, the ejection of this high velocity electron or β-particle does not alter the mass of the parent atom.

We have in radioactive transformations, accordingly, two general processes, one in which an α-particle or helium nucleus is emitted and the other in which a high speed electron or β-particle is projected from the nucleus of the parent atom. Since an α-particle has two units of positive charge, the total net charge on the nucleus of a radioactive atom decreases by two units after the ejection of an α-particle. The atomic number of the transmuted element is accordingly two units less than that of its parent. The new element belongs to the family two columns to the left in the Periodic Table. When a β-particle is emitted, the nucleus loses one unit of negative charge. The net positive charge therefore increases by one unit; the atomic number increases by one; and the new element belongs to the family one column to the right of its parent in the periodic table.

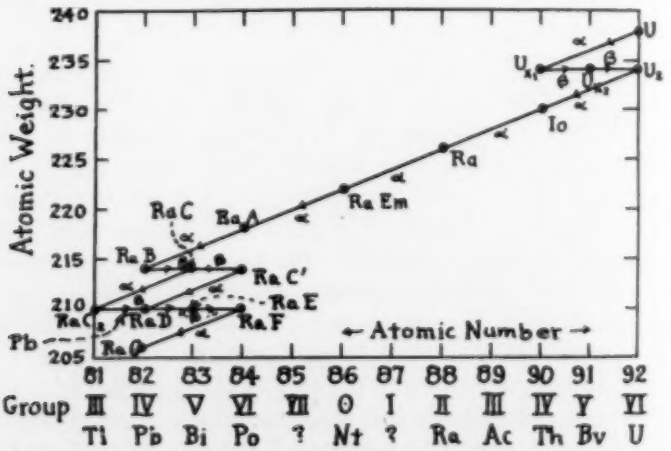


Fig. 14. Transmutation Products of Uranium by Radioactive Disintegration

Fig. 14 illustrates this clearly for the entire radioactive group related to radium. Here we have plotted atomic number versus atomic weight. Uranium, a metal of Group VI, atomic number 92, atomic weight 238, emits a helium nucleus and becomes an atom called UX_1, for lack of a better name, a material belonging to Group IV, identical chemically to ordinary thorium and having an atomic number 90 and atomic weight 234. Then follows the emission of two β-particles resulting in U_{II}, an isotope of uranium and exactly similar to uranium except that it weighs four units less. Uranium II is transmuted into ionium and helium; ionium is transmuted into radium and helium; radium is transmuted into niton and helium; niton is transmuted into radium A and helium; radium A is transmuted into radium B and helium. Up to this point the original atom has emitted 6 α-particles. The atomic weight of radium B is accordingly $4 \times 6 = 24$ units less than that of its first ancestor, uranium, or 214. Radium B then emits a β-particle becoming radium C without change in mass. Here it has a choice in regard to its mode of disintegration. Radium C which is chemically identical to bismuth may emit a helium nucleus and become RaC″ which is chemically identical to thallium, or it may emit a β-particle and become RaC′. Whichever course the atom decides to take, it eventually becomes RaD, an isotope of lead, and then, after the successive emission of two β-particles and one α-particle, the spontaneous disintegration is brought to a close with RaG or lead.

What a wonderful history this lead atom has had! Nature has produced from the uranium atom 15 different atomic species besides eight atoms of helium. Nine of these products may be differentiated by ordinary chemical or spectroscopic analysis; the others are isotopes of some of these fundamental nine, elements of different mass but having the same chemical properties. After being subjected to internal revolution after revolution the torn and distracted uranium atom finds haven as an atom of lead. Only so far as Mother Nature is concerned, however, for it is the intention of the alchemist to continue this process of trial and tribulation in order that lead may be transmuted into gold.

We have described but one family of the radioactive metals. There are two other families, one known as the thorium series and the other as the actinium series. The general mode of disintegration is similar to that of the uranium series. Thorium is transmuted successively into one element after the other, finally becoming lead. Actinium likewise is transmitted into a series of elements and here again the series is closed, as far as Mother Nature is concerned, with the comparatively worthless metal lead. Besides these transformations, potassium and rubidium emit β-rays, probably becoming calcium and strontium respectively. There is further the

possibility that many of the other elements are radioactive but to so slight a degree that the effect is not definitely measurable. Certain experiments have indicated merely the suspicion of radioactivity in ordinary laboratory apparatus, which of course may be due to the actual presence of a recognized radioactive element as an exceedingly minute impurity.

What do these transmutations teach the alchemist? No one is anxious to convert a few milligrams of radium, of which he may be the proud possessor, into a corresponding amount of lead pipe. Nor need one worry seriously lest this occur. The rate at which the spontaneous transmutations take place is sometimes very slow. Thus if one possessed a gram of radium to-day, half of it would still remain as radium after 1,600 years. The production of radium from uranium might appear to be a profitable occupation as uranium is comparatively inexpensive, but here again the time required is too long to interest a single individual. Half of the uranium with which the process is initiated would be converted into uranium X_1, the first stage in the transmutation toward radium, only after the interval of five billion years.

What causes the spontaneous emission of an α-particle from the nucleus of a radioactive atom? We know that the nucleus of the uranium atom, itself a complicated structure, is surrounded by 92 planetary electrons which revolve with tremendous velocity, each in its own elliptical orbit. The orbits are not exactly elliptical however; they are perturbed by the repulsive actions of the other electrons. Each electron therefore travels in a path which may be described as a rosette or an ellipse with a progressive motion of perihelion. At perihelion it can be shown that the electrons in highly elliptical orbits almost penetrate the complicated structure of the nucleus of a heavy atom. It is not difficult to imagine that occasionally the configuration of the nucleus is such that one of these outer electrons at its instant of nearest approach may exert a very large influence upon component parts of the nucleus with which it is nearly in contact. Suppose the revolving electron pulled the α-particle just a small distance from the nuclear electrons which tend to hold it in the nucleus. The electrostatic repulsion of the rest of the nucleus is then sufficient to eject the α-particle from the atom with the tremendous velocity observed experimentally.[5] Now the reason that such a state of affairs happens only

[5] Stated conversely, the computation of this distance on the assumption that the velocity of the ejected α-particle is due wholly to the electrostatic repulsion of the rest of the nucleus gives values comparable with nuclear dimensions, and with perihelion distances for electrons in orbits of high eccentricity. For example, the distance $7 \cdot 10^{-12}$ cm is sufficient to account for the emission of α-particles from uranium with the observed velocity $1.37 \cdot 10^{9}$ cm/sec.

once in an eon, as far as the life of the uranium atom is concerned, may be due to the small probability that the perturbed orbits of the planetary electrons assume just exactly the correct relative positions in order that the forces which the electrons exert may be in resonance with the oscillations in the nucleus itself. If the alchemist had at his command magnetic fields of the magnitudes which must locally exist within the nucleus it is *possible* he could hasten these perturbations and reduce uranium to radium in a reasonable length of time. We are not able to produce such fields but there are other methods available by which the nuclear structure may be influenced, especially with the lighter elements.

We have found that radioactive elements eject helium nuclei and electrons from their nuclear structures. This fact suggests that the nuclei of all atoms are made up of helium nuclei possibly cemented together by the nuclear electrons. The atomic weight of an element should be accordingly an integral multiple of 4, the atomic weight of helium. This is true for a great many elements, but we have elements of atomic weight $4q+1$, $4q+2$, $4q+3$ where q is an integer. The integers 1, 2, and 3 are thought to arise in hydrogen nuclei also present in the nuclear structure. Accordingly, it has been conjectured[6] that the nucleus of any atom is composed of three different types of building block, the hydrogen nuclei or protons, the helium nuclei or α-particles, and electrons. By properly combining these three units we may correctly represent the atomic weight and net nuclear charge of any element, as illustrated in the following table.[7] Here α, p and e refer, respec-

[6] Speculations on this date from Prout 1815, but the theory was first put in quantitative form by Harkins who supports it with evidence from various sources. *Cf.* series of papers in J. Frank. Inst., 1922–3.

[7] The true atomic weight of every atomic species except hydrogen is integral, or at least is usually integral to within 1 part in 1,000. Thus ordinary lithium is a mixture of two kinds of lithium atoms, called isotopes since they are chemically identical, one of atomic weight 7 and other 6. These are present in the ratio 94:6 such that the *mean* atomic weight which the chemist measures is 6.94. While there are only 92 elements chemically distinguishable (five of these are as yet undiscovered) there are possibly 200 atomic species which may be separated and weighed by positive ray analysis.

Slight departures from exactly integral values for the true atomic weights of certain isotopes or elements may be expected from theoretical considerations. For example, higher precision in experimental determinations by the positive ray method *may* show that nitrogen weighs 14.015 instead of 14, and already Aston has observed small but definite deviations from whole numbers in the isotopes of tin.

The accompanying table shows the true atomic weights of the elements up to phosphorus, as *observed* by Aston and by Dempster. The formulae for the nuclear structures are, however, purely empirical; the protons, α-particles and electrons have been arbitrarily grouped to give the observed mass and correct atomic number. For the physical justification of such procedure one should refer to the papers by Harkins, *loc. cit.*, where evidence from many sources, both chemical and physical, is correlated.

tively, to α-particles, protons and electrons, and the subscripts show the number of each required. The expression $\alpha_x\ p_y\ e_z$ is a chemical formula for the nuclear molecule.

STRUCTURE OF THE NUCLEUS

Atomic Number	Elements	Formula	Atomic Weight
2	He	α	4
3	Li	$\alpha p_2 e_1$	6
		$\alpha p_3 e_2$	7[8]
4	Be	$\alpha_2 pe$	9
5	B	$\alpha_2 p_2 e_1$	10
		$\alpha_2 p_3 e_2$	11[8]
6	C	α_3	12
7	N	$\alpha_3 p_2 e$	14
8	O	α_4	16
9	F	$\alpha_4 p_2 e_2$	19
10	Ne	α_5	20[8]
		$\alpha_5 p_2 e_2$	22
11	Na	$\alpha_5 p_3 e_2$	23
12	Mg	α_6	24[8]
		$\alpha_6 pe$	25
		$\alpha_6 p_2 e_2$	26
13	Al	$\alpha_6 p_3 e_2$	27
14	Si	α_7	28[8]
		$\alpha_7 pe$	29
		$\alpha_7 p_2 e_2$	30
15	P	$\alpha_7 p_3 e_2$	31

Accordingly, if we could disintegrate the atoms, the atomic weights of which suggest the presence of hydrogen in the nucleus, we should be able to cause the ejection of hydrogen, in analogy to the ejection of α-particles by radioactive elements. To do this should obviously require considerable energy since atoms are stable in ordinary chemical reactions. Rutherford hoped that the high velocity α-particles, 12,000 miles per second, emitted by RaC would have sufficient energy to penetrate the nuclei of the lighter elements and produce disturbances leading to disintegration. This work proved successful. To Rutherford belongs the distinction of being the first alchemist who definitely transmuted one element into another by artificial means.[9]

It was found that by bombarding boron, nitrogen, fluorine, sodium, aluminium and phosphorus with α-particles of a known energy, hydrogen nuclei were projected from these atoms with

[8] More abundant isotope; *cf.* Aston "Isotopes"—Arnold, 1922.

[9] This may be stated more moderately although such conservatism is unusual. Rutherford was the first to *discover* that nitrogen or aluminium, for example, could be disintegrated by α-particles, a phenomenon which must take place in nature wherever these elements are in contact with a radioactive material. The process is artificial, however, as is the production of a synthetic ruby, because it may be controlled at will in the laboratory. Rutherford's recent work is summarized in four semi-technical lectures which contain references to the original sources. *Proc. Roy. Soc.*, *97*, pp. 374–400, 1920; *Nature*, *110*, pp. 182–5, 1922; *idem*, *112*, pp. 305–12, 1923; *Science*, *58*, pp. 209–21, 1923.

enormous velocities and energies. The identification of the hydrogen nuclei was effected by measurements of their deflection in a magnetic field. Rutherford's experiments are especially conclusive because in every case the energy of the ejected H-nucleus, considered initially at rest, is *greater* than that which it should have derived directly from the impacting α-particle. That is, the α-particle merely disturbs the equilibrium in the nucleus of the disintegrated atom, and it is the repulsive force of the nucleus which contributes materially to the velocity of the ejected hydrogen particle.

This fact eliminates the possibility that the observed hydrogen particles were due to the presence of hydrogen gas as an impurity. Thus it may be shown from simple dynamics, and may be verified directly by experiment, that when α-particles are projected through hydrogen gas, the maximum energy of an ejected hydrogen nucleus, produced by a head-on collision, is 0.64 that of the impacting α-particle. Rutherford found, however, that the hydrogen particles, ejected from the six light elements mentioned, possessed more than 0.64 of the energy of the impacting α-particles, and, except for nitrogen, the energy even exceeded that of the α-particle. Thus the hydrogen particles ejected from aluminium possessed a kinetic energy 37 per cent. greater than that of the α-particles producing them, as illustrated in the following table:

KINETIC ENERGY OF HYDROGEN-NUCLEI

Atomic Number	Element	$\frac{\text{Energy of H particle}}{\text{Energy of } \alpha\text{-particle}}$
5	B	1.02
7	N	.79
9	F	1.10
11	Na	1.02
13	Al	1.37
15	P	1.10
1	H	.64

Hydrogen could not be detected when the α-particles bombarded carbon or oxygen, nor indeed should one expect this, for there is no readily obtainable hydrogen in the nuclei of these atoms, their structural formulae being α_3 and α_4 respectively. Whether or not helium may be ejected from the nuclei of these and other light atoms has not been subjected to experimental test. The liberation of helium (or of any particles) of small range or velocity can not be detected by the experimental methods so far devised.[10]

[10] Let us *hope* that Rutherford's negative results with lithium, chlorine and potassium may be explained in such a manner, since the structural formulae for the nuclei of these atoms are similar to those for the elements showing disintegration. However the whole subject is much more involved than this inadequate summary would indicate. One must refer to Rutherford's original papers.

Rutherford's experiments accordingly definitely prove that the nuclei of light atoms may be disintegrated, resulting in the production of hydrogen. The ejection of a single hydrogen nucleus must decrease the atomic weight of an atom by one unit and likewise must correspondingly decrease its nuclear positive charge and atomic number. The disintegration product, if stable, should be therefore the element[11] immediately preceding in the Periodic Table, as represented by Fig. 15.

Phosphorus becomes silicon of atomic weight 30; aluminium becomes magnesium of atomic weight 26; sodium is transmuted into the gas neon of atomic weight 22; boron becomes beryllium of atomic weight 9. Fluorine should become 0^{18}; and nitrogen, C^{12}; but these isotopes are known *not* to exist, so that very likely the ejection of hydrogen from fluorine and nitrogen is followed by other disintegrations in order that stability may obtain. For example, nitrogen might emit both hydrogen and helium and become stable as an atom of beryllium.

With these experimental facts before us we are prepared for the consideration of the real problem of alchemy, the transmutation of the baser elements into gold and other precious metals. But may we pause a moment and reflect upon the economic situation here involved.

If the secret of transmutation of a baser metal into gold is suddenly made public property, and if thereby gold may be pro-

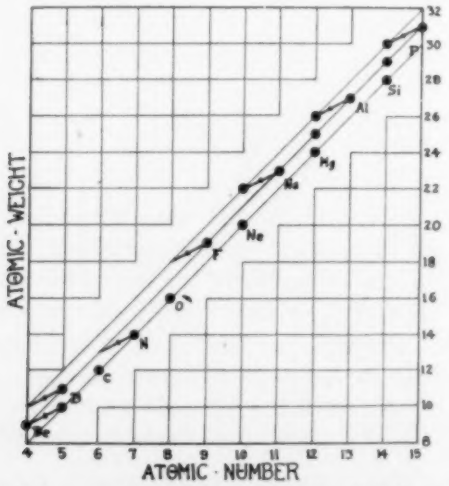


FIG. 15. A reasonable speculation in regard to the disintegration products obtained when hydrogen nuclei are ejected from elements by the Rutherford method.

[11] So far there has been no experimental evidence for this conclusion as the amount of the transformation product is too small for analysis. It is, however, reasonable speculation.

duced in unlimited quantities, at the same cost, for example, as iron, a world-wide financial panic will be immediately precipitated, for the currency of every civilized country is based on a nominal or actual gold standard. All governments could immediately pay their total national and international indebtedness, including reparations. Measured in tons of gold, this is not such a huge quantity as one might expect. The holders of government securities would receive the correct amount of gold for their return, but suddenly this would have lost greatly in purchasing power by virtue of the resulting increase in the volume of currency and decrease in the value of the gold. In the same manner the creditor classes, the holders of securities and mortgages, the savings bank depositors, the life insurance policy holders, their fortunes and equities would be practically wiped out of existence. The debtor classes, the borrowers, for a time would luxuriate in the golden flood of wealth and would be able to pay their indebtedness in bullion now of value chiefly for its luster.[12] Undoubtedly the catastrophic situation may be easily saved by a corps of economists —and these are always available—so let us return to our problem.

In Fig. 16, we have plotted the atomic weights of all the known (or reasonably certain) isotopes of elements from atomic number 77 to 83. We shall consider the production of gold, platinum and iridium by the two conventional methods, that of Mother Nature, where an α-particle is emitted, and that of Rutherford which results in the emission of a hydrogen nucleus.

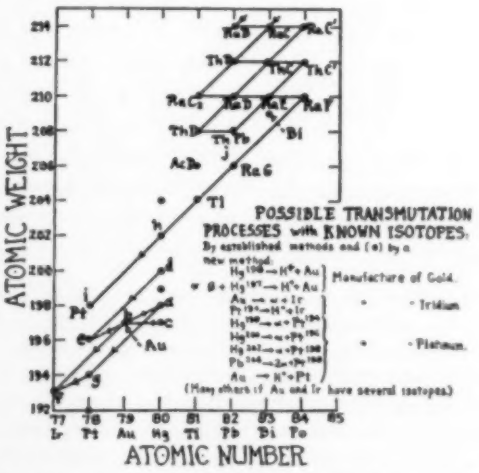


FIG. 16. METHODS FOR PRODUCING GOLD, PLATINUM AND IRIDIUM FROM BASER METALS

[12] These depressing predictions were suggested by my colleague, Dr. F. A. Wolff.

If a hydrogen nucleus is ejected from Hg^{198} by an experiment similar to that of Rutherford's, gold should result as shown by the transition *ab*. If gold can be made to emit an α-particle we should obtain the more valuable metal iridium by the transition *bf*. Performing the Rutherford experiment on Pt^{194} should also yield iridium, as shown by the line *gf*. Ejecting an α-particle from each of the three isotopes of mercury, Hg^{198}, Hg^{200}, Hg^{202}, should produce the three isotopes of platinum Pt^{194}, Pt^{196}, Pt^{198}, these transmutations being indicated by the lines *hi*, *de* and *ag*. From lead of atomic weight 206 we should obtain Pt^{198} after the emission of two α-particles, illustrated by the transition *ji*. The ejection of a hydrogen nucleus from gold by the Rutherford method should result in the production of Pt^{196}, as indicated by the line *be*. Many more transmutations of this type are possible (on paper) if later work shows that gold and iridium possess several isotopes. Still another reasonable means of transmutation is evident if one may drive an electron or β-particle into the nucleus of an atom and compel it to remain there. Thus, in the transition *cb* the nucleus of Hg^{197} attracts to itself a β-particle and becomes a gold atom. One would think that such transmutations should readily occur (experimental evidence to the contrary) since the positive nucleus should exert an attracting force on a negative charge.

These are the conventional or conservative methods for the production of rare metals by alchemical processes. Many other schemes have been proposed and tried but they rest upon a less secure, experimental foundation. For example, some have thought that transmutations may be effected by very high temperature. Now temperatures approaching 50,000° may be obtained by exploding metal wires with sudden application of high voltage and capacity. Wendt[13] has claimed that by so disintegrating a tungsten wire, a quantity of helium 26,000 times as great in volume as the original wire resulted. The tungsten was therefore practically completely dissociated into helium from which it must have been originally synthesized. Bell and Bassett[14] have found that the

[13] *J. Am. Chem. Soc., 44*, pp. 1887–94, 1922. The work is very questionable—in fact it is quite certain that the conclusions were based on unreliable data; others have failed to substantiate his results. However, the fact that huge quantities of energy per atom are involved in disintegration is not an argument, although frequently so stated, that anything like a similar quantity of energy is required to initiate the reaction. Radioactive transformations require no outside agency. The chief argument against disintegration by high temperatures is the fact that even at 50,000° the energy exchanges between atoms are far smaller than may be produced by electronic bombardment, while the latter has proven so far ineffective.

[14] *Science, 56*, p. 512, 1922. One can not find fault so easily with this work. The minute quantity of helium present in the atmosphere is certainly insuffi-

Sperry search-light arc shows seven lines of helium in its spectrum. Whence the origin of this helium if not from the disintegration of carbon or of the atmospheric gases?

Thus if high temperature is required, there are means for its production and the process can be readily commercialized. At present, however, methods involving electrical stimulation appear more definite and promising. The yield of transmuted elements so far secured is unfortunately very small, discouragingly so in fact. From Rutherford's experiments we find that if all the α-particles[15] emitted by a gram of radium and its products in a year were fired into an aluminium target, the liberated hydrogen would amount to 1/1000 cubic millimeter, with a correspondingly small amount of the transmutation product magnesium. Even were the product gold, the method, as so far developed, could not be looked upon as a menace to our present money standard.

Our hope must be therefore in some means for producing α-particles in tremendous quantity and with energy several times that of the fastest α-rays known in radioactive disintegration. There is a possibility that such hopes may be fulfilled. A helium ion falling through a potential difference of 4 million volts will have an energy equal to that of the fastest α-particles. X-ray bulbs have been made to operate at one tenth of this voltage. Much may be accomplished when electrons and ions may be driven through electric fields of a dozen times the magnitudes now available.[16] Possibly the general x-radiation from tubes of such high voltage may be employed for the disruption of atomic nuclei and for the transmutation of metals.

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cient to give the observed spectrum. If the helium was not produced by disintegration it must have been present in considerable amount as an impurity, which is obviously surprising.

[15] The number of α-particles emitted in a year attains the stupendous figure $4.5 \cdot 10^{18}$, four and one half billion billion. However, this amounts to less than 0.2 cm³ of helium gas at atmospheric pressure. The large number of molecules in a small quantity of matter has been vividly illustrated by Aston, J. Frank, Inst., *195*, pp. 581–608, 1922, as follows: "Take a tumblerful of water and label all the molecules in it. Throw it into the sea and wait for a period sufficiently long that all the water on the earth, in seas, lakes, rivers and clouds is perfectly mixed. Then fill the tumbler from any hydrant. It will contain 2,000 of the original molecules, for although the number of tumblers of water on the earth is $5 \cdot 10^{21}$ the number of molecules of water in a single tumbler is 10^{25}." It may be noted that, at 25 cents per trillion, one German mark will still buy 1,150,000,000 atoms of gold.

[16] Experiments at the maximum voltages now attainable are worth while. Several years ago Dr. Trivelli, later of the Eastman Kodak Co., bombarded uranium with high-voltage electrons and obtained some evidence that the radioactivity of the material was increased. The experiments were not continued to the point where definite conclusions could be drawn.

Even if transmutation should be carried out on a large scale of production, its importance to the general welfare of humanity would shrink to insignificance compared to the greater interests which would develop simultaneously. However much may be the good arising in the use of non-corroding girders, in the replacement by platinum of our structural steel buildings and bridges;—however great may be the happiness of the housewife with an array of platinum utensils in the kitchen;—all these are really trivial. No alchemist of the past dared dream of the field opened to the modern physicist, the moment that transmutation is reduced to quantity production. For by whatever means this be effected, the same methods can be employed in the creation of energy by annihilation of mass.

We know from the theory of relativity that energy and mass are associated in the relation $E = c^2m$ where c is the velocity of light. There is more real alchemy in this little equation than in all the thousands of volumes written from the time of Hermes to Lavoisier. Can we grasp the significance of the numerical magnitudes here involved? Let us consider one of the simplest possibilities.

While it is proven that atoms are made up of protons, α-particles and electrons, we are convinced that the ultimate building blocks are simply two in number, the protons and the electrons. The α-particle or helium nucleus is therefore produced by the union of 4 hydrogen nuclei and two cementing electrons, as shown in Fig. 11. The helium atom *may* be synthetically constructed from 4 hydrogen atoms. That helium actually consists of hydrogen should be capable of verification by the Rutherford method of disintegration, so soon as we are able to produce bombarding α-particles with only four times the energy at present available.

Now we know that the atomic weight of helium is 4.00, while the atomic weight of hydrogen is 1.0077. Hence four separate atoms of hydrogen weighs 4.031, or 0.031 units more than when they are compressed together to form an atom of helium. Thus the formation of 1 atom of helium annihilates 0.031 units of mass, and, by the general principle of Einstein, results in the creation of c^2m units of energy. If a gram atom of hydrogen is thus converted into helium, the energy liberated is

$$c^2m = .0077 \times 9 \times 10^{20} = 6.9.10^{18} \text{ ergs.}$$

That is, if the hydrogen in two teaspoonsful of water be converted into helium, 200,000 kilowatt hours of energy is set free, representing $20,000 worth of electrical current or ten thousand dollars to the teaspoonful.

This is a comparatively moderate reaction from the speculative standpoint. Since mass is undoubtedly electrical in nature one may wonder what would happen if the nucleus of the hydrogen

atom should attract into itself an electron. If the nucleus and electron could be united, their charges should completely neutralize one another. It is possible that the original charges should therefore cease to exist and the atom should vanish. The complete annihilation of one gram of hydrogen in this manner would give rise to 130 times the energy available in the formation of helium or $2,600,000 in electrical power. The ancient alchemist desired to create gold. The modern alchemist would destroy it. Complete destruction of one pound of gold represents the production of 10,000,000,000 kilowatt hours of energy.

While these are mere speculations, indeed, so sure are we of the fundamental truth of the alchemical transmutation of hydrogen into helium that the chief scientific interest[17] no longer lies in the consideration of its *possibility*. The real problem from the scientific standpoint is the explanation why all hydrogen has *not* been already transmuted into helium. With such an exothermic reaction why should we have any hydrogen or hydrogen compounds at all? Tolman[18] has given serious thought to this question, which has puzzled the alchemist, and his paper may be commended to those who fear lest even the water disappear from the universe, and we really die of thirst.

In conclusion we have found that some forty different elements or atomic species are transmuted spontaneously in radioactive disintegrations. Many radioactive elements give off helium. The light elements may be transmuted into still lighter elements and hydrogen. We have learned how gold and other precious metals may be made from lead or mercury. When the scientist is able to utilize an electric field of 10 million volts there is small doubt but that every element may be produced by transmutation.

To do this on a large scale of production, to make it a commercial enterprise, is an entirely different proposition. I doubt if many of us will live to see its realization. But when that time comes, this world will be a true haven of rest for all its inhabitants. There will be no poverty, no suffering and no labor; atomic energy will do the work for all mankind. Humanity will be emancipated by the scientist.

Such emancipation is probably desirable, but philosophically it raises a very interesting question. Shall we ever be content to retire from all industrial and intellectual activity and, with atomic energy enslaved, submit to a life of ease and stagnation? I believe not. New problems will be opened requiring even more intense scientific study than those which at present engage our attention.

[17] Speculatively speaking.

[18] *J. Am. Chem. Soc., 44,* pp. 1902–8, 1922.

Possibly this world where we now live will no longer prove a satisfactory abode for the civilization of the future. Problems such as exploration of the stellar space will confront the daring navigator with atomic energy at his command. New worlds may be discovered, so attractive that the inhabitants of this earth all will migrate leaving their former home to the mercy of the processes of evolution. . . .

Life here is again evolved through the millions of years; intellectual development again advances to the discovery of atomic energy; the people leave, and so the cycle is repeated, forever and forever.

Now in benediction, may I counsel those who are discouraged and are disappointed in the present status of alchemy, to take comfort in the Proverbs of Solomon, the 16th chapter and the 16th verse, wherein it is written "How much better it is to get wisdom than gold."[19]

[19] Similar advice will be found in the First Epistle of Peter, 1:7.

ADJUSTING AGRICULTURAL PRODUCTION TO CHANGING CONDITIONS

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It is quite apparent to any one who gives the matter serious attention that things are not moving smoothly with the farmer; that he is confronted with certain conditions quite different from those prevailing a generation ago, and that these changed conditions call for some adjustments in crop production and management before he will attain that degree of prosperity and stability to which he has been accustomed. It is perhaps in order to inquire what are some of these changed conditions.

In the first place, there has been a remarkable change in the character of the population of this country. In 1890 there were about 63 millions of people within our borders; in 1920, nearly 106 millions, or an increase of over 67 per cent. in 30 years. In 1890, 43 per cent. of our population lived in cities and incorporated villages and 57 per cent. in strictly rural territory. In 1920, 59.9 per cent. lived in cities and villages and 40.1 per cent. in rural territory, and of the latter only 29.9 per cent. can be classed as belonging definitely to our farming population; in round numbers, less than 32 millions. While *relatively* the farming population has decreased, actually there has, of course, been an increase amounting to some 18 per cent. as compared with 67 per cent. increase in total population.

The farmer finds himself to-day, then, in a country the vast majority of whose inhabitants are engaged in pursuits other than agriculture.

Increase in Agricultural Output

A second change of moment is the greatly increased agricultural output per man. This is brought out quite strikingly when one compares the average annual production of our leading crops in the decade 1889–1898 with similar production in 1909–1918, as follows:

LEADING CROPS OF UNITED STATES

Crop	10-year average production 1889 to 1898 Bus., tons or bales	1909 to 1918 Bus., tons or bales	Percentage increase in 2d period
Corn	1,949,592,500	2,736,424,000	40.3
Oats	760,090,800	1,278,982,400	68.2
Wheat	536,507,400	756,176,900	41.0
Barley	91,850,200	199,815,500	117.5
Rye	30,138,400	48,013,200	59.3
Potatoes	214,989,300	369,903,700	72.0
Hay	52,414,600	74,263,600	41.7
Cotton	8,657,900	12,728,600	47.0

This average increase of over 50 per cent. in the production of the most important staples (omitting rye and barley) is far out of proportion to the increase in rural population. It is proper to note briefly the causes of this increased production. Undoubtedly the most important cause has been the introduction and general use of a truly marvelous line of agricultural implements, thus multiplying the efficiency of the individual man several times for some lines of work. Then the increased use of commercial fertilizers has been an important factor in the older cultivated sections, and finally, the application of science to the art of farming has contributed not a little.

It is quite apparent that we do not need as large a proportion of our population on the farm now as we needed 30 years ago. Indeed, if one were to judge from the present price of many of our staple products a few more farmers might well devote their energies to other lines of industry.

RELATIVE PRICES

A third change which is causing great unrest in the agricultural world and is likely to call for some adjustments in production is the price of agricultural products as compared with the price of labor, farm implements, taxes and transportation, particularly the price now as compared with prices before the war. In making these comparisons use is made of what is called the "index number," which is the price relation at a given time to the average price of the commodity for a stated period of time taken as a standard or 100 per cent. In this case the average of the pre-war period 1910–1914 is taken as 100. An index number of 125 accordingly means 25 per cent. above the average price during 1910-1914.

INDEX NUMBERS OF PRICES AND WAGES

1910–1914 = 100

Average for year	Farm products	All commodities	U. S. union wage rate	Farm machinery
1914	105	100	104	102
1915	106	103	105	102
1916	125	130	109	108
1917	194	181	116	138
1918	222	198	136	175
1919	236	210	158	178
1920	222	231	203	175
1921	126	150	209	176
1922	136	152	197	153
1923	144	157	215	165

But the present agricultural situation will be understood better if the large group of farm products be separated into certain specific products. For instance, in December, 1923, corn had an index number of 124, wheat 107, hay 106, potatoes 136, onions 176, butter 161, hogs 95, beef cattle 100, wool 209.

The wide range in prices will at once be noted. With farm labor ranging from 134 in North Dakota to 185 in New York, and averaging for the entire United States 162, with farm machinery at 165, freight rates at 155 and taxes on farm real estate at 204, it is at once seen where the wheat, corn, hay, hog and beef cattle farmer is placed. It should be stated that 85 per cent. of the corn crop is fed to livestock and marketed as such.

Now it must be granted that the farmer got his raise in prices, *first*, as shown by the index numbers table, and might properly expect to take the first drop, but until some items enumerated more nearly approach his standard he will be at a decided disadvantage and have just cause for complaint.

ADJUSTING PRODUCTION

Evidently this situation does call for some adjustments on the part of the farmer. Shall he keep on growing his usual acreage of wheat and corn and maintain his accustomed numbers of hogs and cattle? No general rule of practice can be laid down. Some farmers and localities should most certainly curtail their acreage of these standard crops, while others might well increase their production. It will perhaps turn some light upon the agricultural situation to consider the comparative acreage of our staple crops in a number of representative states. The following table shows what percentage of total acres in harvested crops is in each of several of our leading crops:

STAPLE FARM CROPS IN MANY STATES

State	Total acres in harvested crops	Percentage of this acreage in: Corn	Wheat	Oats	Hay and forage[1]	Potatoes
Iowa	21,609,534	41.7	6.7	25.0	21.1	0.45
Illinois	21,462,852	36.9	19.1	20.1	18.7	0.40
Indiana	13,223,256	33.8	21.2	13.0	25.0	0.47
Ohio	13,934,239	25.6	21.0	10.4	35.4	0.90
Kansas	22,843,587	16.1	49.3	6.2	21.9	0.20
Nebraska	19,432,145	34.5	22.1	10.5	21.9	0.50
So. Dakota	15,313,006	18.0	25.3	12.0	33.1	0.40
No. Dakota	19,760,741	9.7	46.0	10.5	20.5	0.40
Missouri	16,810,354	33.1	27.2	10.2	25.0	0.40
Minnesota	17,149,813	13.9	22.1	20.0	29.4	1.90
Wisconsin	10,265,998	11.1	5.2	22.0	44.1	2.90
New York	8,904,678	3.6	5.1	10.5	61.8	3.50
Michigan	10,000,611	12.7	10.6	15.1	36.4	2.80
Maine	1,650,189	0.4	0.9	7.2	77.8	7.0
Montana	3,924,337	0.5	43.3	4.9	43.0	0.6
						Cotton
Texas	25,534,195	18.6	9.5	7.3	9.4	45.2
Georgia	12,537,645	34.1	1.1	1.5	10.0	37.7
So. Carolina	5,852,376	30.2	1.4	3.4	11.5	45.4
Oklahoma	15,393,796	16.1	30.5	10.2	13.5	17.7
Mississippi	6,603,052	40.3	0.1	0.8	7.3	44.7
Alabama	8,091,496	41.1	0.4	1.0	8.7	32.4

And the following table gives one an idea of the situation as regards our livestock industry:

THE NUMBER OF ANIMALS PER 1,000 ACRES OF HARVESTED CROPS

State	Milk cows	Other cattle	Swine	Sheep
Iowa	56	161	487	43
Illinois	54	72	250	28
Indiana	57	59	293	53
Ohio	78	60	221	152
Kansas	22	111	130	13
So. Dakota	30	101	198	45
No. Dakota	27	41	33	13
Montana[2]	49	310	69	604
Minnesota	98	74	221	25
Wisconsin	216	83	163	33
New York	183	44	63	61
Alabama	64	58	136	11

It is perhaps unnecessary to call attention to these tables in detail. The information carried is quite evident. Some of the storm centers in our present depression are apparently due to too

[1] All silage crops.

[2] Only 3,924,337 acres in harvested crops.

large a proportion of the acreage in cultivated crops in one crop which for the time being is low in price. Low-priced wheat will hit North Dakota and Kansas harder than Wisconsin, Michigan and Ohio. Moreover, it is all but universally true that the states with the largest acreages grow less bushels per acre than states with small acreages, thus greatly increasing their losses.

What is true of crops like corn and wheat is not necessarily true of hay and forage, which are often of the nature of by-products and are generally consumed by local livestock. Instead of sources of trouble, these large acreages may be evidences of a well-balanced agriculture.

What shall be said, then, in the matter of agricultural adjustments? In the first place, it may well be said that radical changes are not called for. The fact that wheat or corn is low in price one year is not proof that it will be low the next year. In times of peace the yearly average farm price of corn has changed 70 per cent. in 12 months' time, and the total production has shifted 55 and 60 per cent., with less than one per cent. change in the acreage planted to corn. It is not an unusual thing for wheat to vary 25 and 30 per cent. in average yearly price, one year following another. Hurried adjustments of acreages to take advantage of high or to avoid low prices are foredoomed to disappointment. The adjuster will usually find himself a year or two behind the crest of high prices.

But greater diversification is assuredly in order in many localities. It would seem to be apparent that states like North Dakota and Kansas, not to mention others, would do well to reduce their acreage of wheat somewhat and increase that of other crops fairly well adapted to the state, and likely keep more livestock. With freight rates as they are now, or as they are likely to be in the near future, more attention must be given to supplying the home market and perhaps less to the foreign market. In the great changes which have taken place in our population previously referred to in this paper, a goodly portion of our foreign market of other days has been set down within our own borders. This naturally calls for large increases in truck crops, fruit and milk. As we properly supply these needs there will be some easement in the foreign market situation.

And "home market" should include not only the United States, one's own state and nearby cities, but the farmer's actual needs in his own home. Not many farmers are supplying as many of their home needs as they might profitably do. The old-time "independent" farmer no longer exists. He can be found only in the pages of fiction. The farmer of to-day depends quite largely upon the department store of the great city and the town grocer and baker.

There should also be as much concentration of products which have to be shipped long distances as possible—more eggs, butter, wool, etc., and less cereals and roughages.

Greater Economy in Production

The agricultural situation will also be greatly helped by more economical production. Anything which will reduce the cost of producing a bushel of wheat or a pound of pork will increase the farmer's net profit as much as an increased price for his product, and will be better than the latter, for it will not tend to decrease the demand for his product as an increased price would have some tendency to do. The latter would also have a tendency to increase the cost of living all around, the farmer included.

Among the things which will make for economy in production is a larger yield per acre. The cost of growing 80 to 100 bushel-to-the-acre corn and 40 bushel wheat is but little more than 30 to 40 bushel corn and 10 to 15 bushel wheat. The farmer who is able to "adjust his production" in the direction of the larger yields mentioned is the one who is going to reap the greater rewards in agriculture.

There are a number of things which will aid the farmer in reaching these desired yields. Among them may be mentioned a reduction in the number of acres farmed. During the period of the war many acres were put under the plow and into the production of harvested crops that could be used with profit only in times of very high prices. Their productive power is too low to return a profit at the present time. The best thing that can be done with this acreage is to put it back in pasture where some of it was previously, and some of it in forestry, until the time comes when it can be farmed with profit. This concentration on a reduced acreage will result in higher yields per acre and increased profits.

Unquestionably a larger use of legumes would result in more profitable crop production. At the present time less than one acre in seven of our harvested crops is in legumes, and a large proportion of this so-called legume acreage is only part legume—a timothy and clover mixture. It is doubtful whether we average to have our land in legumes more frequently than one year in eight, in the country as a whole. What would it mean in the way of increased yields per acre if we had legumes one year in four? We have no data showing this fact, but we do have data showing the difference between growing clover one year in five and one year in three. This difference is 7½ bushels of corn per acre and 2¼ bushels of wheat, in favor of clover one year in three. It is fair to presume that legumes one year in four, as compared with one year in eight, would at least mean as much—probably more.

A larger and more general use of commercial fertilizers and of calcium compounds is destined to be an important factor in increasing the yields per acre of all agricultural and horticultural crops. The older cultivated sections have long used these materials with profit, and the corn belt and the northwest are beginning to use them. The proper combination of fertilizing materials for different soils and crops is well worked out, or is fast being done, by the state agricultural experiment stations.

The gains to be secured from the use of the best available varieties of all farm crops are very important in the matter of greater economy in production. Varieties of cereals, for instance, have been developed in many states which will increase the average yields from two to four bushels per acre. Methods of seed inspection and certification of these improved varieties have been put in practice which make the distribution of seed of high quality fairly certain. In some few states these improved varieties are grown on from one fourth to one half or more of the total acreage of the state.

It is important not only that seed of excellent varieties be used, but careful attention must be given to seed treatment and spraying. Potato growing in our best potato sections has made rapid strides recently by the use of disease-free seed and thorough spraying. Our fruit industry has been reborn by the diligent attention given to spraying. New materials for use in spraying and new uses of old materials are continually coming to light. Without doubt developments of great moment will be made in the near future in conquering plant diseases and insect enemies. In some plants, red clover, for instance, much remains to be done in the way of breeding disease-resistant strains.

While great strides have been made during the last 30 years in agricultural output per man, there is no reason to believe that the limit has been reached. New and valuable labor-saving implements are continually coming into use. Men are becoming more proficient in both the science and art of farming. When four million men left the farm to engage in the activities of the World War the complaint that the production of agricultural supplies for our armies and essential industries must necessarily be greatly curtailed was very general. But, strange to say, agricultural production was not reduced. Rather it was expanded to such an extent that the great worry now is how and when can we get back to normal production.

A very little investigation will show that there are almost unbelievable differences in the amount of crop acreage cared for per man in different parts of the country; yes, in different parts of the same state. Some of these differences are perhaps necessary, but many of them are matters of precedent and education. A better

organization of the farm plant; a more intelligent utilization of farm machinery will revolutionize agricultural profits in many sections.

After all is said and done the farmer will very largely have to work out his own salvation. He has done this many times in the past and he can and will do it again. His one unfailing remedy for low prices is to ease up on production—cut out cropping some of his least productive acres and sell some of his labor to nearby industries or public works when the latter offer more for labor than he can get for it on the farm.

It is said that over a million farmers left the farm for other activities during the past two years. This is not as great a calamity, perhaps, as some might think. There are evidently more men engaged in farming at the present time than are needed. If they can get better wages elsewhere is there any reason why they should not better themselves, and in bettering themselves, better conditions for those who choose to remain on the farm?

Some of these times the index number for wages will bear a different relation to farm products than it does to-day. When that time comes the drift will set in the other way. While this may seem slow and cruel, there is no evidence to date that there is any better way. As a nation we love to legislate things right, but some things do not readily yield to Congressional edict.

THE PACIFIC SCIENCE CONGRESS

By Professor HERBERT E. GREGORY

YALE UNIVERSITY AND BERNICE P. BISHOP MUSEUM

Preliminary Steps

The Pacific Ocean is a region from which information is meager. It has many interesting problems of its own and not unlikely holds the key to the solution of problems elsewhere. Within the Pacific and around its borders scientific exploration has progressed intermittently for a century; especially during the past quarter century scientists have been actively at work in this region. Government bureaus of the United States and Canada, supplemented by universities and scientific institutions of British Columbia, Washington and California, have recorded much essential information for the Pacific Coast of North America. New Zealand has made important contributions to the natural history of the dominion, together with its outlying islands; Australia is slowly gaining knowledge of its continent and due to the energy and foresight of these two British countries, knowledge of Antarctica has become the possession of the world. For the Dutch East Indies economic studies are far advanced and preliminary reports on geology, botany and zoology have appeared. Since its founding in 1906, the Bureau of Science at Manila has made remarkable progress in gathering data from the 7,083 islands which constitute the Philippines. Japan is as well mapped and described as any Pacific region. In Hawaii science has passed the exploratory stage.

Little is known of the great land masses, Papua and Borneo, and of the islands which lie between them. But the least known part of the Pacific, perhaps of the world, is the lands and waters of Micronesia, Melanesia and Polynesia—a region of islands scattered over about one sixth of the earth's surface. These islands, perhaps 20,000 in number, include some like Fiji, New Caledonia, Tahiti and Rarotonga, for which scientific knowledge requisite for half-hearted commercial exploitation has been recorded, and others for which through the activities of missionaries an outlined picture of the native inhabitants exists, still others for which the knowledge of natural history has received no additions since the days of their discovery. The natural history of many charted islands is unknown, and some have probably never been landed upon. For a large part of the Pacific the standard works of reference are the accounts of Captain Cook, and of such voyages as those of the *Astrolabe*, the

Beagle and the Wilkes Expedition. To gain knowledge of this vast region adequate for even the most urgent needs of science requires the development of a somewhat unusual program.

The Pacific is peculiarly a region where scientific work by the "hit-or-miss," "free lance" method is ineffective. Experience in the study of coral reefs, of former land connections, of race origins and migrations, of the history of Pacific land snails, insects and plants have revealed complexities quite beyond the range of individual workers. To collect single-handed the significant data bearing on even a small division of a small subject would require the years of a Methuselah; and the expense involved in bringing scientific knowledge of the Pacific to the stage reached on the mainland of the United States is beyond the resources of most scientific institutions. Thus it has come about that many of the contributions to Pacific science have increased bibliographies rather than knowledge.

To produce the hoped-for results the essentials seem to be: a group of sympathetic men representing institutions interested in Pacific science, cooperating to save time and thought and funds; a common program of work carefully arranged so that the observations and studies of one group of specialists are directly usable by other groups.

It is with these views in mind that individuals, institutions and governmental agencies have joined in plans for Pacific investigations and, as a means of facilitating the work, have organized the Pacific science congresses. Now that these congresses seem likely to attain a permanent place among scientific organizations it seems desirable for historical reasons to record the steps which have led to them and to indicate their scope and purpose.

Like most movements which later result in action, plans for systematic Pacific exploration doubtless have been more or less definitely formulated by many individuals. Few readers of the scientific accounts of Darwin, Dana, Ellis and Langsdorff could lay aside those works without wishing for more extended descriptions, and the many publications of travellers who have found their way to the Pacific point out the opportunity for investigation of unknown areas. To fertile minds within and on the border of the great ocean, the call to exploration must have been insistent and it is not surprising to find schemes for Pacific investigations developing in Hawaii and in California. In 1898 Charles R. Bishop, founder of the Bernice P. Bishop Museum at Honolulu, formulated plans for general Pacific studies in consultation with the officials of the National Museum, and arranged for expeditions to the Marianas Islands in 1900 and to the southern Pacific in 1903.

In 1907 the Pacific Scientific Institution was incorporated under the laws of Hawaii, "to encourage in the broadest sense and most liberal manner investigation, research and discovery in the Pacific Ocean and to make application of knowledge thereof to the improvement of mankind." Although financially well supported, the institution appears to have lacked the leadership necessary to carry its work beyond a preliminary stage.

The idea of promoting joint discussion of Pacific problems began to take form at the Australian meeting of the British Association for the Advancement of Science in 1914.

In 1915 the Pacific region received attention at the Panama-Pacific Historical Congress,[1] which formed part of the educational program of the Panama-Pacific International Expedition. The program of the American Association for the Advancement of Science, which met at San Francisco, also in 1915, included a number of papers on Pacific topics, among them one by Daly[2] which discussed means and methods for further exploration.

In 1916 the attention of the National Academy of Sciences was called to the condition of scientific work in the Pacific through a "Symposium on Pacific Exploration," arranged by Professor W. M. Davis—a discussion which resulted in the appointment of a Committee on Pacific Exploration. Further impetus was given the movement by the Conference on International Relations which formed part of the program arranged for the Semi-Centennial of the University of California in 1918 and by the symposium on "Exploration of the North Pacific," the leading feature of the meeting of the Pacific Division of the American Association for the Advancement of Science in 1919.

At the Honolulu Conference the close of the war projects for Pacific work again came up for discussion and, with a view to uniting all interests in a single organization, the Committee on Pacific Explorations appointed by the National Academy was transferred to the National Research Council, with Professor J. C. Merriam as chairman. With changes in personnel and in name it has become the Committee on Pacific Investigations, attached to the Division of Foreign Relations. The deliberations of this committee, supplemented by informal conferences and extensive correspondence during the years 1916–19, brought out clearly the size and complexity of scientific problems centering in the Pacific and showed the advantages to be gained through coordination of the efforts of individuals, institutions and governments interested in the Pacific.

[1] "The Pacific Ocean in History," edited by H. Morse Stephens and Herbert E. Bolton. The Macmillan Company, 1917.

[2] Daly, R. A., "Problems of the Pacific Islands": *American Journ. Science*, Vol. XLI, pp. 153–186, 1916.

As a means of promoting the desired cooperation, the committee assumed the responsibility of arranging for a conference at which representative scientists from New Zealand, Australia, Java, China, Japan, Canada, continental United States, Hawaii and the Philippines might be present. As a place of meeting the claims of different Pacific cities were considered, but the view prevailed that a conference organized and directed by a committee of the National Research Council should appropriately be held within the United States. The committee therefore accepted the proposal of representative citizens of the Territory of Hawaii that the conference meet in Honolulu in 1920 under the auspices of the Pan-Pacific Union—a Hawaiian organization devoted to developing friendly relations among the different nationalities of the Pacific, especially among those races which constitute the population of Hawaii. From the standpoint of the committee on Pacific investigations the advantages at Honolulu were its strong group of scientific men familiar with Pacific problems, the well-known hospitality and generosity of its leading citizens, and the keen interest of its population in questions which affected the welfare and prosperity of Pacific peoples. A cordial welcome and adequate financial support could be taken for granted.

The scope and purpose of the Honolulu conference is indicated by the following announcement which accompanied invitations:

> The purpose of the conference is to outline scientific problems of the Pacific Ocean region and to suggest methods for their solution; to make a critical inventory of existing knowledge, and to devise plans for future studies. It is anticipated that this conference will formulate for publication a program of research which will serve as a guide for cooperative work for individuals, institutions and governmental agencies.
>
> The program of the conference is in the hands of the Committee on Pacific Exploration of the National Research Council.
>
> The meetings will be arranged to place emphasis on the following topics:
>
> (1) The present status of knowledge of the various branches of anthropology, biology, geography, geology and related sciences in so far as the Pacific Ocean region is concerned.
>
> (2) Research desirable to inaugurate projects to be described in considerable detail with reference to their significance and their bearing on other fields of study. Investigations designed to lay the foundation for a higher utilization of the economic resources of the Pacific may be included.
>
> (3) Methods of cooperation with a view to eliminating unnecessary duplication of money and energy.
>
> (4) The best use of the funds now available and the source of further endowments.

Compared with some other international scientific gatherings, this first general conference on Pacific subjects presented some unusual features. It was a conference of individual scientists rather

than of official representatives of governments and institutions. As a matter of courtesy, complimentary invitations were sent to a selected list of universities, museums, scientific institutions and heads of federal departments, but the particular aim of the committee was to bring together men whose knowledge of the Pacific and interest in its unsolved problems was likely to result in profitable interchange of views.

Financially, the conference was made possible by the guarantee of a group of citizens, appointed by the Governor of Hawaii, and acting as a committee on the Pan-Pacific Union. Before the close of the conference considerable territorial funds were made available and these, supplemented by the direct and indirect contributions from local scientific, commercial and social organizations and a federal grant—designed primarily to insure the attendance of scientists in government bureaus—proved abundantly adequate for the payment of travelling allowances, costs of publication and entertainment.

Preliminary organization of the conference was effected by a temporary chairman and a committee on preliminary program, acting jointly for the Committee on Pacific Investigation of the National Research Council and the Pan-Pacific Union. When the conference convened, the duties of this chairman and this committee came to an end and throughout its sessions the conference was completely autonomous. It elected its own permanent chairman and other officers and committees, arranged the program from day to day and made provision for future meetings. In order to give time for a personal interchange of views, the program was so arranged that the first week of the conference was devoted to presentation of papers, the second to excursions and informal discussions, and the third to formulation of plans for future cooperative work.

The published reports of the conference[3] show the focusing of attention on comprehensive topics and formulation of programs for investigation. Topics of local and of individual interest were given little place. The subjects chosen for discussion call for contributions from several branches of knowledge. The resolutions likewise call for research in general rather than in specific problems. The topics which received the fullest consideration are: "Race relations of the Pacific;" "Program for anthropological research in Polynesia;" "Origin of Hawaiian fauna and flora;" "Fisheries of the Pacific;" "Biological institutions in the Pacific region;" "Program for work in Pacific volcanology;" "Seismology of the Pacific;" "Mapping of the Pacific;" "Pacific ocean currents in relation to organisms;" "Status of areal geologic mapping in the Pacific

[3] Proceedings of the First Pan-Pacific Scientific Conference: Bernice P. Bishop Museum, Special Publication No. 7, 1921.

region;" "Correlations of post-cretaceous formations in the Pacific region;" "Symposium on means and methods of cooperation;" "Symposium on training of scientists for Pacific work."

The attendance of professional scientists at the conference was 93, distributed as follows: Mainland of the United States, 23; Japan, 4; Australia, 6; New Zealand, 3; the Philippines, 4; Canada, England, China, 1 each; Hawaiian delegates from the staffs of the University of Hawaii, the Volcano Research Association, the Sugar Planters Experiment Station, the Bishop Museum and the federal and territorial scientific bureaus, 39.

After provision for publication and for interchange of information had been made, with votes of thanks to the organizations and individuals whose generosity and courtesy had surrounded the delegates with facilities for effective work under pleasing conditions, the First Pan-Pacific Conference adjourned with a strong feeling that the conference marked a definite forward step in scientific investigation. Fundamental problems had been outlined and important contributions to facts and principles and methods had been made; close personal relations had been established and the necessity of submerging national "interests" "spheres of influence" and "rights" in a cooperative effort to gain fuller knowledge of the Pacific had been recognized.

It was, therefore, with regret that the conference found itself faced with the necessity of adjourning *sine die:* it was in no position to effect a continuing organization or even to arrange for a second meeting. For, although the committee of the National Research Council stood ready to organize another conference on American territory, it was recognized that effective international cooperation involved invitations to future conferences emanating from countries other than the United States. The hope was expressed that New Zealand or Australia might extend an invitation to be followed in turn by Japan and Canada. These hopes have been realized in the Pacific Science Congress which met in Australia, August 13 to September 3, 1923, by an invitation to meet in Japan in 1925, and by the prospect that Canada may arrange for a session in 1929.

The Australian Congress

The Australian Pacific Science Congress (1923) presented features of special interest in its organization, conduct and program. As compared with the Honolulu conference it was broader in scope, more generously financed and exerted a wider appeal. Unlike the Honolulu conference, in which the government took no direct part, the Australian Congress was an official governmental affair. It was financed by the commonwealth government and by the state

governments of Victoria and New South Wales; invitations were issued to other countries through the departments of state and arrangements for the congress were intrusted by the government to the National Research Council of Australia, which in turn placed the responsibility for the scientific program in the hands of a Science Congress Committee. For making local arrangements for meetings of the congress in Melbourne and in Sydney, state committees were also formed. The official control extended to the selection of general officers, chairmen and secretaries of sections, and committees charged with the conduct of the meetings. The delegates were guests invited to a previously prepared intellectual feast in the arrangements for which they had no responsibility. Outside of the sessions of the congress, entertainment was provided on a remarkably generous scale. Each delegate was the personal guest of some interested citizen, and federal, state and city officials joined in offering hospitality. Many local excursions were arranged to suit the wishes of delegates and, without cost to them, the way was opened for visits to Tasmania, to the Central desert, to the Great Barrier Reef and to more distant localities involving a transcontinental journey.

Some of the papers presented at the Melbourne and the Sydney sessions were technical discussions of map-making, earthquakes, geological formations, classification of plants and of animals and similar topics of chiefly professional or local concern; but the distinguishing character of the congress, especially of the Sydney session, was the serious but optimistic discussion of matters of vital importance to dwellers in the Pacific. The program made provision for general and for sectional meetings. The general meetings were arranged with a view to bringing the knowledge and experience of all the scientists to bear on outstanding general problems, especially those which call for international cooperation; the eleven sectional meetings, attended chiefly by specialists, permitted discussion of details. Such topics as "general structure of the Pacific and its influence on plant and animal life," "coordination of scientific work in the Pacific region," and "the relation of the climate of the Pacific to economic and social life" received much attention. The control of insect and plant pests was a section topic for three days, and the conditions controlling the expansion of Pacific agriculture and fishing and stock-raising were treated at length at the congress, and gave rise to discussions in the daily press. The greatest popular interest was shown in the conferences dealing with the dwindling native races in Polynesia, Micronesia and Malanesia, and in the discussions and public lectures on the eradication of tropical diseases. The interest developed more and more as the evidence came in from

Tahiti, New Zealand, Fiji, the Philippines and Java that sanitation, medical skill and sympathetic administration might reproduce throughout the Pacific islands the conditions in American Samoa, where the native population has increased 42 per cent. during the past 20 years. In its highest sense, the Australian meeting was a conservation congress in which the fundamental problems underlying the development of resources were discussed by an unusual group of competent scientists.

In addition to the large number of Australian scientists and laymen the congress was attended by 82 overseas delegates, distributed as follows: Great Britain, 12; the Netherlands, 2; New Zealand, 13; Japan, 11; the Philippines, 5; Dutch East Indies, 4; British Malaya, 2; Hawaii, 6; Canada, 3; United States Mainland, 17 (including 7 appointed by the secretary of state); and one each from France, Chile, Hongkong, Fiji, Tahiti, New Guinea and Papua.

As a result of the deliberations of the Australian Congress, projects were outlined and formulated in a series of resolutions.[4] They may be classed as follows:

(1) *Projects preferably to be carried out by the governments primarily concerned:* These include: Sail surveys of Pacific islands; completion of the international topographic map; establishment of a geophysical and astronomical observatory in the Caroline Islands; botanical surveys of Macquarie Island, the Aleutian Islands and Krakatoa Island; geographical survey of Fiji; maintenance of the observatory in British Samoa; establishment of a seismological and volcanological station at Rotorua; provision for transmission of daily time signals from Papeete, Funabashi, Cavite, Bandung, Perth, Adelaide, Melbourne, Sydney and Wellington; establishment of scientific time signal at Pearl Harbor.

(2) *Projects chiefly concerning Australia:* Establishment of a Bureau of Entomology, a federal geologic survey and topographic survey, a solar physics observatory and a forest products laboratory; a study of the Great Barrier Reef; provision for the teaching of anthropology in Australian universities; provision for the publication of the work of the Toolangi Magnetic Observatory; a veterinary survey of Papua.

(3) *International committees:* The following committees were appointed by resolution with instructions to report at the Japanese session of the Pacific Science Congress: on selection of critical areas of crustal unrest; on methods of investigation of salinity, temperature and currents of Pacific waters; on the status of genetic research now in progress; on arrangements for daily records of

[4] Gregory, Herbert E., "Resolutions adopted at the Australian Meeting of the Pacific Science Congress," *Science*, Vol. LVIII, pp. 502–507, 1923.

static at wireless stations and on permanent organization and draft of a constitution.

(4) *Uniform records:* Many of the field notes and specimen labels relating to the published and unpublished investigations of past and present students of the Pacific have been made without reference to the needs of fellow-workers and because of this satisfactory correlation is impossible. To avoid the continuance of this condition, the general adoption of uniform field records and labels was recommended—specifically, for botany, the forms in use in Java, the Philippines and Hawaii; for anthropology, the field record devised for the Bayard Dominick Expedition. It is believed that with suitable recording blanks the observations of amateurs and laymen may be directly utilized.

(5) *University instruction:* Resolutions call attention to the dearth of treatises and the absence of university courses designed to train students for Pacific work, particularly in economic entomology, botany and anthropology.

(6) *Conservation:* Reservation of land on which the tallest eucalypts stand and of Australian timber-bearing areas; setting aside of areas in the Pacific for the preserval of unique fauna and flora; reservations for restoring depleted herds of fur seals, sea otters, whales, elephant seals and dugongs; survey of the organic productions of the Pacific; a study of the insect pests of sugar cane and of other tropical agricultural plants. The Congress resolved that "the scientific problem of the Pacific which stands first in order of urgency is the preservation of the health and life of the native races."

General Comment

The two Pacific science congresses have been characterized by seriousness both among the delegates and by the communities in which they were held. As with other scientific gatherings, personal relations were strengthened and enlarged, the results of interesting discoveries and observations were presented, and a few young men were given the opportunity to make their initial bow to the scientific world. But these features were incidental to the main purpose of the gatherings, which was to bring the facts and methods of the different branches of science to bear directly on one problem. The desire to advance the interests of anthropology, botany, geology, geography and zoology was submerged in the earnest purpose to make these subjects contribute to the welfare of the people within and around the Pacific. This purpose was the more readily attained because most of the delegates to both congresses represented governments and institutions which had not only recognized responsibili-

ties, but also authority and financial means. The resolutions adopted are not generalized statements of obvious possibilities in the advancement of science; they relate to urgent, well-defined pieces of work within the scope and means of the institutions and government bureaus concerned. Most of the investigations called for by the Honolulu Conference have been completed or are in progress and work has already begun on several projects outlined by the Australian Congress. All of them involve specialists in different branches of science and financial support from more than one source.

The serious meaning of the Pacific congresses is recognized by the communities in which the meetings are held. Experience has brought the conviction that science holds the key to the development and utilization of the natural resources of the Pacific; that Pacific agriculture, stock-raising and fisheries can be made profitable and social life agreeable only in so far as the habits of insect and plant pests, animal breeding, distribution of fish and conditions surrounding physical and mental health of the native and introduced human population are understood. Doubtless for this reason, leading citizens have attended both congresses as listeners (more than one thousand persons were present at some of the meetings in Sydney) and the discussions of the congresses have been treated by the newspapers as "front page stuff" to a degree unknown on the United States mainland. The demand for the Proceedings of the Honolulu Conference long ago exhausted the supply. Doubtless, also, for this reason financial support has been abundantly forthcoming. For the Honolulu Conference, in addition to time freely given by many individuals, the financial contributions of Hawaii from the Territory, individuals and scientific commercial and social organizations amounted to about $30,000. For the Australian Congress the amount contributed directly or indirectly reached a total estimated at $75,000.

The subject-matter of the congresses so far held lies chiefly in the field of ethnology and natural history with their obvious ramifications into mathematics, psychology and the social sciences and within this field no attempt has been made to distinguish between so-called "pure science" and so-called "applied science." It is probable, however, that physics and chemistry will be represented at future congresses, and it appears not unlikely that in association with these congresses or through a separate organization provision may be made for cooperative investigations in Pacific history and economics.

THE PHYSICAL BASIS OF DISEASE

II. LOCAL TISSUE DEATH

By THE RESEARCH WORKER

STANFORD UNIVERSITY

"As our second group of diseases," continued the research worker, as the train pulled out of North Platte, "I have selected diseases caused by rupture, loss, death or destruction of important tissues. You are familiar with diseases of this type in external parts of the body. The type is also common in internal organs.

"Rupture, loss or death of external parts of the body may be caused by numerous agents. Mechanical violence, for example, may produce the various types of incised or contused wounds with which you are familiar. Death of tissues may result from exposure to heat, cold, X-ray or chemical agents. A frequent cause of death of external tissues is the action of disease-producing microorganisms. These use the tissues as food, or kill them with their chemical products."

"The germ theory is nonsense," said the man from Boston.

"Our knowledge of the destruction of tissues by microorganisms is no longer in the theoretical stage. It is part of established biological science. Microorganisms are readily visible in killed tissues. They may be isolated from these tissues. Tissue death may be produced by them in laboratory animals. A certain microorganism that was isolated from war wounds, for example, if injected into the leg of a guinea-pig will kill and digest this leg. Twenty-four hours later, the leg is reduced to a bag of dead skin filled with a soft putty-like mass containing naked bones and tendon shreds.

"One of the less common causes of death of external parts of the body is interference with local circulation. The blood vessels, as you know, are muscular tubes, opening and closing under the influence of the nervous system. By electrical or chemical stimulation, arteries may be thrown into such strong contraction that circulation practically ceases. In certain neurotic individuals prolonged contractions of blood vessels occur, sufficient to cause death of fingers or toes. Local circulation may also be interfered with by rupture of the main artery supplying a part, or by the plugging of this artery with solid masses brought from other parts of the body. Circulation may be also stopped by the local clotting of the circulating blood."

"I thought clotting was due to exposure to air," said the manufacturer.

"There is a constant tendency of the circulating blood to coagulate. Coagulation is normally prevented by several factors. Among these are the rate of bloodflow and the physical condition of the blood vessel walls. Clotting within blood vessels can be produced in experimental animals by prolonged local stagnation of the circulating blood, or by injuring the blood vessel walls."

2

"Death of external parts of the body is followed by local reparative processes. The first of these processes is the formation of a zone of demarcation between the living and dead tissues. This demarcation zone is characterized by the multiplication of certain local cells and by local deposits of white blood corpuscles. The new-formed cells and locally deposited corpuscles penetrate a short distance into the dead area. These cells and corpuscles are capable of digesting dead tissues. The dead mass is liquefied at the point of junction with the living parts. This ultimately leads to its mechanical separation from the living body.

"Certain lower animals have the power of regenerating lost parts—a new leg, new claw or even a new brain growing from the stump of living tissue. In human beings, however, regeneration of external parts is practically limited to the skin and underlying supporting tissues. The exposed living tissues are gradually covered by ingrowing skin. On aging, the new skin usually contracts, forming white, semi-bloodless scar-tissue. This contraction is often sufficient to cause puckering or deformity of adjacent structures.

"Aside from its local effects, loss or death of surface tissues may cause serious constitutional symptoms. The exposed subcutaneous tissues, for example, furnish an easy portal of entry for disease-producing microorganisms. These may eventually reach important internal organs. Blood-clots set free from superficial blood vessels may be carried to important internal parts. Chemical products absorbed from the dead tissues may seriously injure internal tissues. Enough toxic substance is absorbed from superficial burns, for example, to cause marked degenerations in the heart and kidneys, and even to cause death within a few hours. The action of these toxic substances has been extensively studied on animals, particularly during the late war."

3

"Processes similar to those in external parts take place in internal structures. A good example of death of internal parts is the

rupture or erosion of heart valves in certain types of heart disease. The aortic valve is the simplest example. This valve, as you know, is so shaped as to fold back against the aorta during the contraction of the heart, so as to offer little or no resistance to the forward passage of blood. On the relaxation of the heart, the aortic valve closes, preventing a backward flow of the blood to the heart. Disease-producing bacteria are often deposited on the aortic valve from the circulating blood. By their growth and chemical products they may so weaken the aortic valve that the valve ruptures. The valve may even be completely destroyed by them.

"The effects of rupture of the aortic valve have been studied on experimental animals. A small hook is passed down a large neck artery of a dog till it reaches the heart. With this hook the aortic valve is readily torn."

"What a hideous thing to do to a dog!" exclaimed the man from Boston.

"Such operations, of course, are always done under combined morphine-ether anesthesia or its equivalent. Aseptic precautions are always taken, often superior to the precautions used in human surgery. In twenty years' experience in research laboratories, I have never known of an exception to this rule. Operations on animals are always undertaken for a serious purpose, either to acquire facts necessary for an understanding of human disease, to prepare material to be used in human diagnosis and treatment, or to train medical students.

"The aortic valve thus torn is no longer capable of preventing the backward flow of blood from the aorta. On the relaxation of the heart, a portion of the aortic blood regurgitates, reducing the amount of blood passed forward to the general circulation. The dog heart, however, has remarkable adaptive powers. Within three or four heartbeats, the amount of blood thrown out into the aorta at each heart beat is increased two or three fold. Deducting the amount lost by backward leakage, the volume of blood sent forward to the general circulation is thus restored to normal. A dog with a torn aortic valve experiences no inconvenience in his ordinary activities. I recall one dog taken home by a group of medical students, that developed into the champion fighter of his neighborhood."

"It's immoral to use dogs this way," said the man from Boston.

"This dog was used to train medical students in the pathology of circulation. They obtained first hand knowledge from this animal, which they could have obtained in no other way. This knowledge they applied later to the diagnosis and treatment of human disease. The knowledge so gained has undoubtedly been

the means of saving human life. I feel it would have been immoral for us not to have used this dog for the purpose. Incidentally, the dog was a half-starved stray, was brought to the laboratory with the hair scalded off from a large area of its back, and at autopsy over twenty bird shot were removed from its hind quarters.

"A ruptured or eroded aortic valve has serious consequences in spite of the fact that a practically normal circulation is readily maintained. The normal heart rarely uses more than 10 per cent. of its maximum power. A heart with a ruptured aortic valve is forced to do from two to three times its usual work, in order to maintain normal circulation. Such a heart is constantly working at a capacity equal to that of a normal heart during violent exercise. Its reserve capacity or factor of safety is reduced. It may be incapable of meeting emergency needs of the body. The dog in question developed symptoms of circulatory insufficiency if taken for a half-mile run.

"Rupture or erosion of the aortic valve is usually followed by local reparative processes. The eroded surfaces are gradually covered or converted into scar tissue. On aging, this scar tissue contracts, narrowing the aortic opening. The aortic opening is thus often reduced to half or even a quarter of the normal size. This narrowing introduces a second mechanical factor in aortic valve disease—an increased resistance to the forward passage of the blood to the aorta. The heart automatically compensates for this increased resistance by increasing the strength of its contractions. The general circulation may still be maintained to its normal level. The reserve capacity or factor of safety of the heart, however, is greatly reduced."

4

"A second example of destruction of tissue in internal organs is death of a portion of the heart wall or heart muscle. Microscopically the heart wall is seen to be composed of muscle fibers, held in place by supporting tissues. The nutrition of the heart wall is derived from small branches of the coronary arteries. Each coronary artery supplies a definite portion of the heart wall. A coronary artery is occasionally occluded. The portion of the heart muscle supplied by this artery is deprived of oxygen and nutrition. Death of the individual usually occurs almost instantaneously. One or more of the branches of a coronary artery, however, may be occluded without causing death of the individual. The local muscle fibers die, are liquefied and absorbed, leaving a portion of the heart wall represented only by inert supporting tissues, or scar tissues.

"The effects of death of a portion of the heart wall are less than one would expect. The individual may have no very noticeable

cardiac symptoms. The reserve strength of the uninjured portions of the heart wall is sufficient to maintain normal circulation. Such a heart, however, may be unable to meet emergency demands.

"A third example of death of internal tissues is death of a portion of the walls of the arteries. The nutrition and oxygen supply of all but the innermost layer of the artery wall is derived from minute blood vessels entering the wall from the exterior. These minute blood vessels are frequently occluded. Portions of the artery wall die and are liquefied. Rupture of the artery may take place, or the artery may bulge to form an aneurymal sac."

"Is that what is meant by 'hardening of the arteries'?" asked the manufacturer.

"Hardening of the arteries is a non-technical expression applied to any process increasing the stiffness of the artery wall. The term is occasionally used to designate deposits of lime in artery walls. Small quantities of lime are present in the circulating blood and in all body fluids. Dead tissue in any part of the body undergoes chemical changes that tend to cause a local precipitation or deposit of this lime. Sufficient lime may be deposited in dead portions of an artery wall, for example, to change these portions to almost stone-like hardness."

5

"Loss, death or destruction of tissue frequently occurs in the respiratory system. One of the best examples is cavity formation in tuberculosis. Tubercle bacilli usually gain admission to the body through an external wound or through the gastro-intestinal tract. They are usually brought to the lungs by the circulating blood."

"I thought pulmonary tuberculosis came from inhaling dust," said the lawyer.

"The popular emphasis placed on dust as the main or sole cause of pulmonary tuberculosis is not in accord with our present experimental evidence. It is almost impossible to infect normal laboratory animals with tuberculosis by causing them to inhale infected dust. Tubercle bacilli, however, injected into any part of the body, often gain admission to the blood stream and are deposited in the lungs. Large areas of the lungs may be killed by these micro-organisms. The dead areas are gradually liquefied and partly absorbed. The unabsorbed residue is usually changed to stone-like hardness by lime deposits. If a fairly large bronchus is included in the dead area, however, this bronchus may be eroded, and the partially liquefied dead portions of the lungs discharge to the exterior. This leaves an open space or cavity in the lungs which is usually surrounded by a zone of scar tissue.

"The destruction of a portion of the lungs is not in itself a very serious matter. There is a large reserve capacity, or factor of safety, in the lungs. Over half of the lungs of a dog, for example, may be removed without interfering with ordinary respiration. The reduction in lung volume, however, is but one of the factors causing symptoms in pulmonary tuberculosis. There is always absorption of toxic substances from the infected area."

6

"Loss, death or destruction of tissue is equally common in the digestive tract. A good example is death of a portion of the intestine following mechanical interference with local circulation. The blood vessels, as you know, reach the intestines by way of the mesentery or intestinal suspensory ligament. The effects of ligating these blood vessels have been studied on dogs. Research workers have found, much to their surprise, that ligation of the main mesenteric artery supplying an intestinal loop is usually without serious effects on that loop. There is a very large factor of safety in intestinal circulation, numerous unions between blood vessels of adjacent portions of the intestine. It is only when the mesenteric artery supplying a very long loop is ligated, and when all mesenteric collaterals are tied that the loop dies.

"Mechanical interference with intestinal circulation sufficient to cause death of a portion of the intestine may be produced in several ways. Mechanically twisting an intestinal loop upon itself, for example, will cause death of the part. Such a twisting of an intestinal loop occasionally occurs after mechanical violence. The twisted loop often possesses a congenitally elongated mesentery. Death of a portion of the intestine is also occasionally brought about by the portion being swallowed by an adjacent intestine. The swallowed portion is passed downward with the intestinal contents."

"Such cases are always fatal," said the manufacturer.

"They are usually fatal if not promptly relieved by surgical methods. Spontaneous recovery, however, occasionally occurs. The swallowed portion of the intestine, for example, is occasionally pushed out before tissue death occurs. Occasionally the swallowed portion sloughs off and is passed out of the body with the intestinal contents, the two segments of the intestine growing together at the point of swallowing."

7

"Probably the most interesting examples of loss, death or destruction of internal tissues are found in the nervous system.

The simplest of these is pressure paralysis. It occasionally happened in pre-Volstead days that a man went to sleep with his arm over the back of a park bench, and woke up with his fore-arm paralyzed. The paralysis usually passed off in a few days, but occasionally lasted for weeks or months. Recovery, however, eventually took place. Microscopic examinations of such cases show an injury to the main nerve trunks at the point of pressure, with death and disintegration of the nerve fibers beyond that point. The disintegrated fibers are gradually absorbed. New fibers gradually grow downward in the nerve trunks from the nerve stump. These new fibers make connections with the muscles. Voluntary movements are resumed.

"A slightly more complex example of tissue death in the nervous system is seen in infantile paralysis. The causative agent of infantile paralysis finds the gray matter of the spinal cord extremely susceptible to its influence, so that areas of this gray matter are killed. This gray matter, as you know, contains nerve cells whose prolongations or fibers pass downward along the nerve trunks to the muscles. The muscles or portions of muscles receiving fibers from the dead area are permanently paralyzed."

"We have a case near us," said the manufacturer. "The paralysis wasn't permanent. At least, it is very much improved."

"Outside of the portions of the gray matter actually killed by the infectious agent, minor injuries are produced in adjacent portions, from which recovery gradually takes place. These minor injuries usually give temporary paralysis. The part of the paralysis due to actual death of gray matter is permanent.

"Another example of death of portions of the spinal cord is seen in late stages of syphilis. The killed area in such cases usually does not include the gray matter, but is confined to certain portions of the white matter. The portions of the white matter thus destroyed contain fibers carrying sensations from muscles, joints and tendons. The individual has little or no knowledge of the degree of relaxation or contraction of his muscles, or of the position of his extremities. Such individuals usually guide their movements by the sense of sight. They are often unable to stand or walk after dark. The dead portions of the spinal cord do not regenerate."

"I have an acquaintance with locomotor ataxia," said the manufacturer. "He could hardly walk two years ago. He gets around fairly comfortably now."

"The destruction of sensation is rarely complete. Much can be accomplished by systematic training or education of the residual sensations. Your acquaintance has undoubtedly had such systematic training."

8

"Very complex symptoms may be produced by loss, death or destruction of portions of the brain or of adjacent nerve trunks. One of the commonest causes of death of portions of the brain is rupture or occlusion of brain arteries. The factors of safety in the brain circulation are very small compared with those of the intestine, so that occlusion of almost any brain artery leads to death of portions of the brain.

"The effects of tissue death in the brain and adjacent nerves vary with the location and extent of the portions involved. If certain relatively small brain areas are destroyed, death of the individual results almost immediately. Large areas, however, may be destroyed without causing death of the individual. There are often marked motor or sensory disturbance. The various sensations, as you know, pass along definite paths, or relay of paths, in the brain. Destruction of any part of this path interferes with these sensations, causing various types of partial or complete blindness, deafness, loss of olfactory or gustatory sense, or of the sense of equilibrium. Muscular movements are initiated in certain brain areas, and pass along definite paths or relay of paths. Destruction of any part of this path gives partial or complete paralysis, or interference with muscular coordination and control. Partial or complete loss of certain memories may follow destruction of certain brain areas. The symptoms following destructive lesions in about a third of the brain are fairly definitely known. Destruction of other portions of the brain gives less definite symptoms. They show themselves mainly in reduced mental powers and alterations in character."

"Alterations in character!" said the man from Boston. "The soul can't be changed by a little injury to the brain."

"That depends on your conception of the relation between the soul and the brain. There are biologists so bold as to believe it will eventually be shown that all phenomena we include under the term mind or soul are merely manifestations of brain activity. They believe no factor is concerned in mental life except the ordinary physical and chemical factors in the nerve cells. According to their belief, destruction of parts of the brain destroys part of the mechanism necessary for the formation of the mind or soul. Most people, however, look upon the mind or soul as a separate entity, living in or working through the nervous system. According to their belief, destruction of parts of the brain destroys part of the mechanism necessary for the outward manifestations of the mind or soul. Formal biology has no quarrel with persons who hold either of these views. The subject is beyond the reach of formal science.

"That destruction of certain brain areas will alter conduct or character, however, is well established. Many brain areas serve as inhibiting mechanisms, holding in check automatic, reflex or instinctive tendencies originating in other parts of the body. Destruction of an inhibiting area may readily lead to unsocial conduct. Many a man has been hung or electrocuted as a result of a destructive lesion in an inhibiting area of his brain."

"First call for dinner!" announced a voice from the corridor.

"I have two children somewhere on the train," concluded the research worker. "I'd better round them up before the dining car is filled."

A HUNDRED YEARS OF ELECTRICAL ENGINEERING[1]

By Professor G. W. O. HOWE, D.Sc.

THIS section of the British Association, over which I have the honor to preside, is concerned with the whole field of engineering, civil, mechanical and electrical. Within recent years the great developments which have taken place in each of these branches have necessarily led to a high degree of specialization, with the result that a man may have an expert knowledge of one branch but a very slight knowledge of the other branches; in fact, the scope of a single branch is now so extensive and the amount of research work being done so great that it is impossible to keep abreast of the developments in one's own special subject unless one concentrates upon it to a degree that leaves little leisure for cultivating other branches of engineering. These considerations influenced my choice of a subject for this presidential address. As an electrical engineer, I felt that I should be expected to deal with some branch of electrical engineering—indeed, I should not feel competent to discuss any other branch—but, in view of the facts to which I have referred, I decided not to deal in detail with any single section of the subject, but to review the past development and present position of the subject as a whole.

The time for such a review is opportune. William Thomson, afterwards Lord Kelvin, the only man who has ever been elected three times (in 1874, 1889, 1907) president of the Institution of Electrical Engineers, was born on June 26, 1824. He was closely associated with the British Association and for sixty years took an important part in the meetings. He was president of the Association at the Edinburgh Meeting in 1871, and was several times president of section A. I wonder what the members of the organizing committee of section G would think if the president, in addition to reading his address, offered to contribute twelve papers to the proceedings of the section: this is what Kelvin did as president of section A at the Glasgow meeting in 1876. I can find no record of his taking any part in the proceedings of section G, although his brother, James Thomson, was president of the section at the Belfast meeting in 1874.

If any one event can be regarded as the birth of electrical engineering, it is surely the discovery by Faraday in 1821 of the prin-

[1] Address of the president of the Section of Engineering of the British Association for the Advancement of Science, Toronto, August, 1924.

ciple of the electro-motor; that is, that a conductor carrying a current in a magnetic field experiences a force tending to move it. It is noteworthy that ten years elapsed before Faraday discovered, in 1831, magneto-electric induction; that is, the principle of the dynamo. Four years later, Sturgeon added the commutator or "uniodirective discharger," as he called it, and in 1845 Cooke and Wheatstone used electromagnets, which Sturgeon had discovered in 1825, instead of permanent magnets. It was during the years 1865–1873 that the shunt and series self-excited dynamo, using a ring or drum armature and a commutator of many segments, finally evolved.

The early workers in the field do not appear to have realized the intimate connection between the dynamo and the motor, for, although the principle was discovered by Lenz in 1838, it only appears to have become generally known that the same machine could be used for either purpose about 1850. The principle underlying the whole modern development of electrical engineering—viz., the generation of electrical power by a dynamo, its transmission to a distant point and its transformation to mechanical power by an electric motor—appears to have evolved about 1873. An interesting light is thrown on the subject by a paper read before the Institution of Civil Engineers in 1857 by Mr. Hunt on "Electromagnetism as a Motive Power." In this paper the possibility of driving electromagnetic engines—that is, electric motors—by currents derived from voltaic batteries was discussed in the light of Jacobi's discovery of the back-electromotive force in these machines. He concluded that power so generated would be sixty times as dear as team-power, and that it would be far more economical to burn the zinc under a boiler than to consume it in a battery for generating electromagnetic power. The leading scientists and engineers who took part in the debate all agreed that electromotive power was unpractical and impossible commercially. William Thomson sent a contribution in writing which concluded with the following sentence: "Until some mode is found of producing electricity as many times cheaper than that of an ordinary galvanic battery as coal is cheaper than zinc, electromagnetic engines can not supersede the steam engine." As S. P. Thompson says, "Faraday's great discovery of 1831 notwithstanding, the real significance of the dynamo had not yet (in 1857) dawned upon the keenest minds of the time." Six years before this, Thomson had suggested the experiment of driving a "galvanic engine" from a thermal battery, and had stated the problem in terms which show that he already had a correct grasp of the theory of the efficiency of the electric motor.

It was at the Manchester meeting of the British Association in 1861 that Charles Bright and Latimer Clark read a paper proposing

names for the principal electrical units; the names were "galvat" for current, "ohma" for electromotive force, "farad" for quantity, and "volt" for resistance. This paper led to the appointment of the celebrated Electrical Standards Committee of the British Association, which, after six years of strenuous work, produced the system now adopted internationally.

One of the earliest applications of the dynamo was for lighting arc lamps in lighthouses; in 1863 Thomson, writing to a friend on the relative merits of the Holmes direct-current and the Nollet alternating-current lighthouse machines, says, "Thus Nollet escapes the commutator, *a great evil*, and gets a flame which does not burn one of the points faster than the other. The reverse of each proposition applies to Holmes. *The commutator is a frightful thing* . . . the thing to be done at the requisite speed is appalling. However, Holmes does it successfully. But I believe it can not be done except theoretically without great waste of energy and consequent burning of contact surfaces. . . . *But I believe a large voltaic battery will be more economical than any electromagnetic machine.* I am not quite confident about this, but shall be so soon, as I am getting a large voltaic, and I shall soon learn how expensive its habits are, and multiply by the number required for a lighthouse." This was thirty-two years after Faraday had discovered the principle of the dynamo.

In after years Kelvin lost his dread of the commutator and championed direct against alternating current on every possible occasion. In 1879, when giving evidence before a select committee of the House of Commons on electric light, he even assured them that there would be no danger of terrible effects from the employment of electric power, because the currents would be continuous and not alternating.

The fifteen years following 1863 saw a great development of the dynamo, and in 1878, when a paper was read before the Institution of Civil Engineers on the improvements introduced by Siemens, Thomson made a remark, following a suggestion by Dr. C. W. Siemens, that showed that he had by this time thoroughly grasped the possibilities. He said that he believed that with an exceedingly moderate amount of copper it would be possible to carry the electrical energy for one hundred or two hundred or one thousand electric lights to a distance of several hundred miles. Dr. Siemens had mentioned to him that the power of Niagara Falls might be transmitted electrically to a distance, and he need not point out the vast economy to be obtained by the use of such a fall as that of Niagara or the employment of waste coal at the pit's mouth. In his evidence before the select committee referred to above he gave an estimate of

the copper required to transmit 21,000 horse-power from Niagara to a distance of 300 miles.

In 1881 Thomson returned to the subject in his presidential address to section A at York and said, "High potential, as Siemens, I believe, first pointed out, is the essential for good dynamical economy in the electric transmission of power." He mentioned 80,000 volts as a suitable voltage. In a paper before the section he developed the now well-known Kelvin Law of the most economical cross-section of the conductor. In 1890 the American promoters of the project for utilizing the power of Niagara turned to Thomson for his advice, and he became a member of the commission of experts. He was throughout stubbornly opposed to the use of alternating currents; he wrote, "I have no doubt in my own mind but that the high-pressure direct-current system is greatly to be preferred to alternating currents. The fascinating character of the mathematical problems and experimental illustrations presented by the alternating-current system and the facilities which it presents for the distribution of electric light through sparsely populated districts have, I think, tended to lead astray even engineers, who ought to be insensible to everything except estimates of economy and utility." He was in a hopeless minority, however, in this view, and Niagara Falls were harnessed to two-phase alternators with an output of 3,500 kilowatts each. Kelvin was present at the meeting of the British Association held in this city in 1897, and shocked many people by saying that he looked forward to the time when the whole water of Lake Erie would find its way to the lower level of Lake Ontario through machinery; "I do not hope," he said, "that our children's children will ever see the Niagara Cataract." Although he was apparently very much impressed with the success of the Niagara system, he was not converted from his allegiance to direct currents, for at his last appearance at the Institution of Electrical Engineers, in 1907, he said, "I have never swerved from the opinion that the right system for long-distance transmission of power by electricity is the direct-current system."

The development of the dynamo during the seventies and the simultaneous development of the incandescent lamp led to the general introduction of electric light during the eighties. Attempts to make incandescent electric lamps had been made as early as 1841, when de Moleyns patented one having a spiral platinum filament, and in 1847 Grove illuminated the lecture theatre of the Royal Institution with such lamps, the source of power being primary batteries; but it was not until 1878 that the commercial development of the incandescent electric lamp was begun by Edison and Swan.

One of the earliest complete house-lighting installations was put in by Kelvin in 1881. A Clerk gas-engine was used to drive a Sie-

mens dynamo, a battery of Faure cells was fitted up, and every gas-light in his house and laboratory at Glasgow University was replaced by 16 candle-power Swan lamps for 85 volts. He had to design his own switches and fuses, etc., for such things were almost unknown.

For about twenty years the carbon-filament lamp held the field without a rival for interior illumination, and, although attempts were made to improve its efficiency by coating the filament with silicon, the plain carbon filament only gave way finally to the metal-filament lamp. One of the most interesting developments in the history of electric lighting was the Nernst lamp, which was introduced in 1897; the filament consisted of a mixture of zirconia and yttria, and not only had to be heated before it became conducting but also had to be connected in series with a ballast resistance in order that it might burn stably. The way in which these difficulties were surmounted and the lamp, complete with heater, ballast resistance, and automatic cut-out, put on the market in a compact form occupying little more space than the carbon-filament lamp was, in my opinion, a triumph of applied science and industrial research. The efficiency was about double that of the carbon lamp. About this time, however, a return was made to the long-neglected metal filament. The osmium lamp invented by Welsbach in 1898 was put on the market in 1902, to be followed two years later by the tantalum and tungsten lamps. The latter was greatly improved by the discovery in 1909 of the method of producing ductile tungsten and by the subsequent development of gas-filled lamps in which the filament can be run at such a temperature without undue volatilization that the consumption is reduced in the larger sizes to 0.6 watt per mean spherical candle-power. This improvement of eight times as compared with the efficiency of the carbon-filament lamp has led to the gradual replacement of the arc lamp even for outdoor illumination. The arc lamp was introduced at about the same time as the carbon-filament lamp, the Avenue de l'Opéra having been lit with Jablochkoff candles in 1878. The open arc was developed during the eighties; the enclosed arc, giving long burning hours and thus reducing the cost of re-carboning, was introduced in 1893, and the flame arc in 1899. During the first few years of this century the flame arc was brought to a high stage of development and the consumption brought down to about 0.25 watt per candle-power, but the necessity of frequent cleaning to prevent the reduction of efficiency by dirt and the labor of re-carboning have led to its abandonment in favor of the less efficient filament lamp.

Before leaving the subject of electric lighting I would point out that it is remarkable that the first great application of electric power

should have been for the production of electric light, since it is probably the least efficient of all its applications. The overall efficiency of a small power station supplying a lighting load and having therefore a very poor load factor would not be greater than about 6 per cent. from coal to switch board, the steam-engine being, of course, the principal offender. Of the total power supplied to and radiated from a carbon-filament lamp not more than about 2 per cent. was radiated as light, so that the overall efficiency from coal to light was 2 per cent. of 6 per cent., which means that of every ton of coal burned at the power station with the object of producing light all but about 3 lbs. was lost as heat at various stages of the transformation. Even now, with up-to-date steam plant and gas-filled lamps, the overall efficiency from coal to light is not equivalent to more than 40 to 60 lbs. of coal out of each ton. The electrical engineer may derive a little comfort from the knowledge that the purely electrical links are the most efficient in the chain.

Whilst on the subject of efficiency I might point out that the difference between the prices at which coal and electrical energy can be purchased by the ordinary citizen corresponds to the losses incurred in the power station; that is to say that the cost of the generation and distribution of the electrical energy is covered by the better terms on which the power station can obtain fuel. In Glasgow the writer pays £5 per ton for anthracite to burn in a slow-combustion stove; taking the calorific value of anthracite at 9,000 kilowatt-hours per ton, which is equivalent to 14,000 British thermal units per lb., this works out at 7½ kilowatt-hours for a penny. For electrical energy for heating and cooking purposes the writer pays a penny per kilowatt-hour. This ratio of 1 to 7½ will correspond fairly closely to the overall efficiency of the power station. In view of the high efficiency and convenience of slow-combustion stoves, it is evident that electric heating can not be expected to compete with them for continuous operation; for intermittent heating the question is very different.

Returning from this digression to the development of the direct-current dynamo, it may be noted that the drum armature now almost exclusively employed was invented in 1872 by von Hefner Alteneck, and gradually displaced the ring armature of Pacinotti and Gramme. Although Pacinotti's original ring armature was slotted, smooth armatures were preferred for many years, until the mechanical superiority of the slotted armature caused the disappearance of the smooth core with its wooden driving pegs which were employed to transmit the turning moment from the conductors to the core. The commutator and brushes were a great source of trouble, but by the gradual elimination of unsuitable material and

by better design and methods of manufacture the commutator has been made a most reliable piece of apparatus. The difficulties of commutation, and especially the need of continual adjustment of the brush position, were largely overcome by the invention of the carbon brush by Professor George Forbes in 1885. It should be pointed out that the commutating poles, which have come into use so much in recent years, were originally suggested in 1884, and are therefore older than the carbon brush.

The realization of the idea of supplying electric current from a power station for lighting houses in the neighborhood owed much to the energy and business ability of Mr. Edison. He exhibited his first "Jumbo" steam-driven dynamo in 1881, and installed two sets at Holborn Viaduct in the following year to supply current to neighboring premises. The output of these sets was about 90 kilowatts at 110 volts, which was so much larger than anything previously constructed that the name "Jumbo" was applied to these sets. About 1890 the multipolar type began to replace the bipolar type for the larger sizes. The size of the single units employed in power stations gradually increased with the increasing demand, and by 1895 dynamos of 1,500 kilowatts had been installed.

As in all other types of machinery, the output obtainable from a given size has been gradually increased by improvements in the electrical, magnetic and mechanical properties of the materials employed, and by improving the design so as to remove ever further the limits imposed by heating, sparking, voltage, drop, etc. The freedom from trouble of the enormous number of electric trams and trains, to take only one class, is a testimonial to the reliability of the modern direct-current motor.

The alternator has had a more varied development than the dynamo, mainly because of the absence of the commutator. The necessity of keeping the brush gear stationary and accessible and therefore allowing the commutator and armature to rotate led to an early standardization of type in the D.C. machine. In the alternator there was no such limitation, and whether the field system should be inside or outside the armature and which of the two should rotate were largely matters of choice. There are great advantages in having the armature, which usually carries a high-voltage winding, stationary, and the usual practice has been for the field system to rotate within the armature. The most striking and best-known exception is the umbrella type of alternator installed in the first Niagara power station, in which the field system rotates outside the armature. The design of alternators has been controlled to a large extent by the development of the prime mover. On the Continent of Europe the slow-speed horizontal steam-engine led

to the construction of alternators of enormous diameter in order to get the necessary peripheral speed, the axial length being consequently reduced to a few inches. In several cases these machines reached such a height that the travelling cranes in the erecting shops were useless, and special tackle had to be erected in order to assemble the machines. In England the high-speed marine-type engine was generally preferred, and consequently the alternators had a smaller number of poles and a smaller diameter. All this has now been modified by the development of the steam turbine.

Ferranti was apparently the first to suggest that the power station should be outside the city, at a point convenient for fuel and water supply, and that the power should be transmitted into the city by high-voltage alternating currents. In 1890 he built the Deptford Station for the London Electric Supply Company, and installed 1,000-kilowatt 10,000-volt alternators. This was the pioneer high-voltage underground cable transmission, and much was learned concerning the peculiarities of alternating currents when transmitted over cables of considerable capacity. The following year, 1891, saw the first long-distance transmission by means of overhead conductors in connection with the electrical exhibition at Frankfort-on-Main; three-phase power was transmitted, at 8,500 volts, from a water-power station at Lauffen to Frankfort, a distance of 110 miles.

This development of the use of high-voltage alternating currents followed the development of the transformer. Gaulard and Gibbs patented a system of distribution involving transformers in 1882, and, although their patent was upset in 1888 on the ground of its impracticability, the present method of using transformers for the distribution of electrical power was introduced in 1885, and shown at the Inventions Exhibition in London in that year. Although from 1890 onwards there has been a steady increase in the size of alternators and transformers and in the voltage employed for long-distance transmission, the last few years have seen a really amazing increase in the size of the units employed. In 1913 the largest 2-pole turbo-alternators had an output at 3,000 revs. per minute of about 7,500 kilowatts; such machines are now made up to 30,000 kilowatts, and 4-pole alternators are running at 1,500 revolutions per minute, with an output of 60,000 kilowatts. This increase in size and in peripheral speed has been made possible by improvements, both in the material and in the design. With a bursting speed 25 per cent. above the running speed, the peripheral speed can now be raised to 150 meters per second. Improved methods of cooling and a better understanding of the various causes of loss in the armature have enabled the materials to be used at higher current and flux densities.

This great increase in the size of units is not confined to the steam turbo-generator, as can be seen from the water-turbine sets recently added to the Niagara installation. Whereas the original Niagara turbines were of about 5,000 horse-power, the new ones have an output of 70,000 horse-power at the low speed of 107 revolutions per minute.

The importance of cheap electric power has led to this great increase in the size of the units in the generating stations. Any slight difference of efficiency between a 10,000-kw. and a 60,000-kw. alternator is of little importance, and would certainly not counterbalance the decreased factor of safety due to concentrating the whole power supply in three or four large units, instead of distributing it between a dozen or more units. The reason for the adoption of the smaller number of large units lies almost entirely in the decreased capital cost per kilowatt of plant. In my opinion, however, there are many cases in which too much consideration has been given to this factor, and too little to the importance of a guaranteed continuity of supply.

Of even greater interest than the growth in the size of the units in the power station is the development of the switch control and protective gear, which is such an essential element in the success of the modern power plant. In the early days of electrical supply all the switch-gear was mounted on slate panels in the engine-room; then, as the power and voltage increased, the switches were placed above, below, or behind the board and operated by mechanical links; then they were removed to another part of the building, each enclosed in its own fire-proof cubicle, and operated by means of relays. The modern high-power switch, like the transformer, is oil-immersed in its iron containing case, and is so robust and weather-proof that it needs no further protective covering, but can be placed in the open air. The insulated bushings through which the leads are taken into the case are the most vulnerable points, but constitute no insuperable difficulty at the present time.

The development of these robust and weather-proof switches and transformers has led to the introduction of the open-air substation in cases where alternating current has to be transformed from one voltage to the other, and there is consequently no running machinery. In generating stations also much of the controlling and transforming plant which was formerly housed in the building can now be placed outside, with considerable saving on the cost of the building.

In connection with the conversion of alternating to direct current, mention should be made of the mercury arc rectifier. Great improvements have been made in recent years, especially in Swit-

zerland, and a number of high-power arcs have been installed in sub-stations. Although they have the advantage of doing away with running machinery, the modern rotary-converter is such a reliable piece of apparatus that it is very questionable whether it will be replaced to any considerable extent by the mercury arc rectifier.

Until recently, the only means of producing a large amount of high-voltage D.C. power was by connecting a large number of carefully insulated dynamos in series, as in the well-known Thury system of power transmission. Within the last two or three years another method has been developed, *viz.*, the so-called transverter, which consists of an arrangement of transformers and a system of rotating brushes, whereby a three-phase A.C. supply is converted into an almost steady continuous current. The first apparatus of this type to be exhibited is installed at the British Empire Exhibition at Wembley, and is designed to deliver continuous current at 100,000 volts. It can also be used for the reverse process. It would thus enable a three-phase generating station and a three-phase sub-station to be connected by a direct-current transmission line, thus avoiding not only the maximum voltage of 1.4 times the effective voltage, which was one of Lord Kelvin's objections to the A.C. system, but also all trouble due to the capacity and inductance of the line. Whether the disadvantages of the transverter, when it is fully developed—it is yet in its infancy—will more than outweigh these advantages remains to be seen, but, apart from the transmission of power, the device may have many applications.

Electric traction represents one of the most important branches of electrical engineering. It shares with the petrol motor the distinction of having absolutely revolutionized the methods of transport within a single generation. In its origins it is nearly a century old, for attempts were made in the thirties to apply Faraday's newly discovered principle to the propulsion of vehicles, but, with very primitive motors and primary batteries, these attempts were doomed to failure. The development of the dynamo and motor in the seventies opened the way to further experiments, and at the Berlin Exhibition in 1879 a line one third of a mile long was shown in operation, a locomotive drawing three cars. The first regular line was opened to traffic near Berlin in 1881; it worked at 100 volts and the current was collected from an insulated rail. Toronto was the scene of one of the earliest experiments in America; C. J. van Depoele, after some experiments at Chicago in 1882 and 1883, ran an electric locomotive in 1884 between the street-car system and the Exhibition in Toronto.

The difficulties were enormous. The carbon brush was not invented until 1885, and commutation in a reversible motor with

copper brushes caused great trouble; armature construction and winding was in its infancy; the suspension of the motor and the method of gearing it to the car axles were problems which were solved only after much experience. Rapid progress was made after about 1887, and the closing years of the century saw an enormous development, the elimination of horse tram-cars throughout the world and the electrification of a number of city and suburban railways.

Of the various systems of collecting the current, only two have survived for street-cars, *viz.*, the usual overhead wire and the exceptional underground conduit; in the case of railways there is no necessity for a conduit and the conductor rail is carried on insulators above the ground-level.

Although 500-volt D.C. supply has been standardized for street tramways, the relative merits of D.C. and A.C. for electric railways has been a burning topic for over twenty years, and is now perhaps more burning than ever. It is somewhat akin to the battle of the gauges in the early days of steam railways, for it involves in many cases the problem of through running, if not now, in the not very distant future. Although the three-phase system was successfully installed in Northern Italy, it has grave disadvantages, and the battle now is confined between direct current at an increased voltage of, say, 1,500 to 2,000 volts, and single-phase alternating current. In the latter case there is, moreover, a further question as to the best frequency to adopt, this being usually either 25 or 16 2/3. The development of the A.C. commutator motor to the stage where it was applicable to traction took place during the first few years of this century, and, although in itself it is inferior to the D.C. motor, it introduces so many simplifications and economies in the transmission of the power from the generating station to the train that experts are very divided as to the relative merits of the two systems for main-line electrification.

I can only just refer to the applications of electrical power to chemical and metallurgical processes. Some of these are purely electro-chemical, others are purely thermal, while in many processes the electric current performs the double function of melting and electrolysing. The possibility of electroplating was discovered as early as 1805, but the commercial application of electro-chemistry on a large scale was impossible before the development of the dynamo. Within the last thirty years the provision of an abundant supply of electrical power has led to the creation of enormous electro-chemical industries; I need only instance the production of aluminium, carborundum and calcium carbide. These industries have usually been established near a hydro-electric plant and provide a load of very high load-factor.

I turn now to what may be called both the earliest and the latest application of electricity; that is, its use for transmitting intelligence. One of the greatest factors in the development of our modern life has undoubtedly been the network of wires and cables which has spread over the whole earth, making possible an almost instantaneous transmission of intelligence and interchange of opinions. In the early days of electrical science the discovery of a new property of electricity was followed by attempts to utilize it for this purpose. As early as 1746 there are records of the use of frictional electricity for the purpose, and distances up to four miles were tried. In 1774 Lesage of Geneva proposed 26 wires in earthenware pipes with pairs of pith-balls at the end of each wire, which flew apart when the conductor of a frictional machine was brought near the other end of the wire. A current of electricity was unknown until Galvani's discovery in 1789, and Volta's pile was first constructed in 1792. Carlisle in 1800 found that water was decomposed by passing the current from a Volta pile through it, and this was the basis of the telegraph proposed by Sömmering in 1809, in which 26 wires ended in 26 metallic points arranged in a row along the bottom of a kind of aquarium. By means of a lettered keyboard at the sending end the current could be applied to any wire, and a stream of bubbles caused to rise from the appropriate point, each point being duly labelled with its appropriate letter. The magnetic effect of the electric current was discovered in 1819, and immediately replaced the previous methods in efforts to develop an electric telegraph; except for the attempts to make a high-speed chemical telegraph, all subsequent telegraph systems have employed the magnetic effect of the current. A great many of the fundamental inventions of telegraphy were made in the thirties; the list includes the needle instrument of Cooke and Wheatstone, the sounder of Henry, the dot-and-dash inker of Morse, and the use of the earth as a return by Steinheil. Although the needle instrument is now obsolete, the sounder and Morse inker are still commonly employed. Many have been the devices for increasing the amount of traffic which can be worked over a single line, either by the simultaneous use of the line by a number of operators, as in the quadruplex and multiplex systems, or by punching the messages on paper tapes, which can then be fed into an automatic transmitter working at a speed ten to twenty times that attainable by a manual operator. In the most up-to-date systems the perforation of the tape is done by the operators working an ordinary typewriter keyboard, and the received message is printed in ordinary type, a single wire carrying eight messages simultaneously, four in either direction, at a speed of 40 words per minute.

The need for telegraphic communication between countries separated by water was so much the greater because of the slowness of other means of communication, but the difficulties in laying and maintaining 2,000 miles of insulated wire on the bottom of the sea must have appeared almost insuperable to the early workers; fortunately, however, there were men who had the necessary vision and courage. The flimsiness of the early cables suggests that the pioneers underestimated the magnitude of the problem which faced them, which was perhaps fortunate. A cable was laid between Dover and Calais in 1850; it lived only a single day, but it was replaced in the following year by a successful cable.

The first cable was laid across the Atlantic in 1858, and, although in the light of our present knowledge we know that it could not have had a very long life, its failure after a few weeks of preliminary communication was primarily due to misuse owing to the ignorance of those in charge. Although much costly experience had been gained in the laying of cables in various parts of the world since this first attempt to span the Atlantic, the success of the second Atlantic cable in 1866 was largely due to the scientific ability of Kelvin and to his enthusiastic and untiring application to the project at every stage of the manufacture and laying of the cable. In addition to this, he not only designed the receiving instruments, but superintended their manufacture in Glasgow and their installation and operation. The success of the Atlantic cable was to a large extent a personal triumph for Lord Kelvin. Although numerous improvements have been made in the details of cable manufacture and in the transmitting and receiving apparatus, no outstanding change has been made in recent years in the method of submarine telegraphy.

Turning to another branch of electrical communication, it is no exaggeration to say that modern business life has been revolutionized by the telephone, which will shortly celebrate its jubilee, for it was in 1876 that Graham Bell invented the magnetic telephone receiver, although others, notably Reis, had been working at the problem since 1861. Bell showed his telephone in operation at the Philadelphia Centennial Exhibition in 1876, and Kelvin, who was one of the judges, brought one back with him and demonstrated it to section A of the British Association, at its meeting in Glasgow in the autumn of 1876.

A successful telephone system requires much more than efficient transmitters and receivers, and the great development which has taken place has been largely a matter of improvement in the design of the many elements that go to make up a telephone exchange. The modern manual central-battery exchange, in which one has

only to lift his receiver to call the operator and be connected in a few seconds to any one of 10,000 other subscribers, is a marvel of ingenuity and construction. But this is now gradually being replaced by the greater marvel of the automatic system, in which the operator is eliminated and the subscriber automatically makes his own connection to the desired subscriber. Attention should be drawn to two outstanding inventions in the actual transmission of telephony over long distances, *viz.*, loading and repeaters. It was Oliver Heaviside who in 1885 proposed to improve the range by increasing the inductance of the line. Although this revolutionary suggestion fell on deaf ears for fifteen years, it ultimately proved to be one of the great inventions of telephony; it is of special importance in underground and submarine telephone cables, the electrostatic capacity of which otherwise seriously limits the range. The other outstanding novelty is the introduction of repeaters at intermediate points in long telephone lines. These repeaters are specialized types of low-frequency amplifiers; they were made commercially possible by the invention and perfection of the three-electrode thermionic valve. The attenuated speech currents arriving at the end of a section of line are amplified and thus given a new lease of life before being passed on to the new section. By using a large number of such repeating stations, telephonic communication has been established between New York and San Francisco. But in addition to making such long-distance communication possible, the use of repeaters enables medium distances to be bridged by relatively cheap lines of high attenuation.

One important application of telephony which is not generally known is in the control of transport; the advantage to be gained by controlling the whole railway traffic of a large district from a central office need only be mentioned to be appreciated.

Turning now to radio telegraphy and telephony, one can not but marvel at the rapidity of its development and the inroad that it has made during the last two or three years on the domestic life of the whole civilized world. The theory of Clerk Maxwell in 1864 and the laboratory experiments of Hertz in 1888 found their first practical application in Marconi's Italian experiments in 1895 and his demonstrations in England during the following year. Much of the rapid progress was due to his perseverance, vision and courage in perfecting apparatus for short-distance work, and simultaneously experimenting over long distances, and thus, in the year 1901, settling by actual demonstration across the Atlantic the vexed question as to whether the waves would pass around the earth over distances of several thousand kilometers or go off into space.

The accomplishment of long-distance communication bristled with difficulties, largely due to unsuspected atmospheric effects

which are still little understood; but such progress has been made and is continually being made that one dare not now adopt an incredulous attitude to the wildest dreams or forecasts of what is to be accomplished by "wireless." The commonplace facts of to-day would have appeared beyond the bounds of possibility ten or twenty years ago.

I have attempted to trace, in a necessarily somewhat superficial, but, I trust, none the less interesting, manner the development during the last hundred years of some of the principal applications of electricity to the service of mankind. In preparing this address, I have been greatly impressed by the enormous advances made, especially during the last thirty or forty years, in the mastery of man over the resources of nature, and in the use of these resources to the amelioration of the conditions of life. By the aid of electricity the energy of the coal or of the lake or river a hundred or even two hundred miles away is transmitted noiselessly and invisibly to the city, to supply light and warmth, to cook the food, to drive the machinery, to operate the street-cars and railways.

By its aid one can flash intelligence to the most distant part of the globe, hold conversations with friends hundreds or even thousands of miles away, or sit in one's home and listen to music and lectures broadcast for the entertainment or instruction of all who care to equip themselves with what may almost be regarded as a new sense. Whereas thirty years ago a ship at sea was completely isolated from the life and thought of the world, it is now in continuous communication with the land and with every other ship within a wide range.

In no branch of electrical engineering, however, is there any suggestion of having reached finality; on the contrary, rapid development is taking place in every direction, and we can look forward with confidence to an ever-increasing application of electricity to the utilization and distribution of the natural sources of energy for the benefit of mankind.

PURPOSIVE STRIVING AS A FUNDAMENTAL CATEGORY OF PSYCHOLOGY[1]

By Professor WILLIAM McDOUGALL

We who are workers in the various fields of psychology are happy in the knowledge that our science is rapidly developing, extending its influence into every sphere of human activity. The institution and the success of this section of the British Association are good evidence that our colleagues in the other branches of natural science have recognized the claim of psychology to take its place among those other branches. And, though in Great Britain there are still all too few chairs of psychology, in Canada and America the universities and colleges are now providing abundant opportunities for teachers, students and research workers, opportunities that are being eagerly and fully used.

Yet, in spite of this happy state of affairs, there is manifested among us psychologists a certain uneasiness as to the status of our science, an anxiety lest the psychologist be regarded as not quite really and truly a man of science. This anxiety is, I think, exerting an unfortunate influence on the development of our science, an influence which shows itself in two principal directions.

On the one hand is a group of psychologists, who, actuated by the desire to mark off an exclusive field of study as their province, define psychology as the science of consciousness and would confine themselves to the analytic description of conscious states as complex conjunctions of elements or units of some kind. On the other hand are those who, feeling that such analytic description, whether it resolves consciousness into a complex of sensations or atoms of consciousness, or into larger more complex units (the so-called configurations or *Gestalten*), brings but little light on human nature and conduct, and can hardly claim to be in itself a science, are driven to the opposite extreme; they ignore this realm of facts, alleged to be the peculiar and distinctive field of psychology, and they would bring to the study of man only those methods of observation, description and explanation which are used in the physical sciences. These two tendencies, which, when they are carried to extremes result respectively in what is unfortunately called "structural psychology" and in "behaviorism," although so different in their outcome, are but two expressions of one desire, the desire to

[1] Address of the president of the Section of Psychology of the British Association for the Advancement of Science, Toronto, August, 1924.

make psychology conform to some preconceived notion of what a science is or should be. The "structuralist" aims at marking out a peculiar and exclusive field of objects of study. The "behaviorist" slavishly accepts the physical sciences as his model, and seeks safety from the charge of being unscientific by confining himself to the use of the methods of observation, description and explanation current in those sciences.

Although a very considerable number of psychologists are following these two widely divergent lines (especially, perhaps, in America), I may, I think, take it for granted that to the majority of us neither line is satisfactory. We feel that both are the expression of a lack of courage; of an undue timidity. In face of the imposing edifice of the physical sciences, the one party shrinks back and seeks to define a little field of knowledge altogether peculiar to itself, within which the psychologist can disport himself at his own sweet will without fear of collision or conflict with the other sciences; the other party seeks safety by taking cover in the bosom of the herd, carefully avoiding all speech or action that might, by marking him as a distinctive variety of the species scientist, bring upon him the suspicious glances of other members of the herd.

There is yet a third large group of psychologists who, moved by the same desire as these others, yet seeing that neither group achieves, nor can hope to achieve, a satisfactory science of human nature and conduct, seek to escape from the limitations of both groups by combining the procedures and the conclusions of both. These adopt the analytic description of consciousness (whether of the "sensationists" or the "configurationists") and they accept the mechanistic explanation of conduct of the "behaviorists;" and they seek (by the aid of the principle of psycho-physical parallelism or of epiphenomenalism) to put the two together in parallel columns, to form what can only be called a lame apology for a science.

The very fact that this undue timidity has produced these two widely divergent and aberrant (not to say abortive) types of psychology is its sufficient condemnation. We should take warning from it; we should be led by it to see that a policy of courage is also the policy of safety. I urge that we psychologists are now numerous enough and strong enough to stand together, to form our own herd, a herd in which our more timid members may find the shelter which they crave. In other words, I urge that the time has come when the students of human nature should boldly claim autonomy or, at any rate, dominion-status for their science; they should invoke and boldly apply the principle of self-determination.

I urge that this policy of safety through boldness is justified and demanded at the present time by considerations of three kinds,

in addition to the fact of the unsatisfactory results of the policy of timidity which I have already indicated.

First, psychology has now at its command an immense mass of data, facts of introspective observation and facts of behavior, demanding to be synthesized in our science, not merely to be placed side by side in parallel columns.

Secondly, psychology has found many important fields of application, in education, in medicine, in industry, in the social sciences; and all these require a psychology, a science of human nature, very different from the mere description of consciousness and from the mechanistic explanation of behavior and different also from the parallel-column psychology.

Thirdly, the policy of boldness is abundantly justified by the present state of the other natural sciences.

I propose to dwell briefly upon each of the three classes of consideration in turn. And in relation to each I desire to urge that the most fundamental need of psychology, the first demand to be met by the policy of boldness, is the adoption without reserve of the conception of purposive striving as valid, useful, nay, indispensable and therefore true.

The life of man from birth to death is one long series of purposive strivings. Sometimes, as when he plans his career and sets out to build up a home and a family, his goal is remote and somewhat vague, defined in his mind in general terms only; sometimes it is precisely and exactly defined, as when he goes to eat his favorite dinner at his favorite table in his club; sometimes it is near and yet but vaguely defined, as when, with open mouth and feeble movements of head and trunk, he seeks the nipple of his mother's breast; or when, during an absorbing after-dinner conversation, he reaches out to put a piece of candy in his mouth. There is a vast range of differences in respect of the nearness or remoteness of the goal; and in respect also of the clearness, fullness and adequacy with which he thinks of his goal. And there is also a wide range of differences between his successive strivings in a third respect, namely, in respect of the urgency, the intensity, the concentration and output of energy manifested in his striving at any movement. Yet, in spite of these wide differences, the striving is always one aspect of his waking life. And even in his dreams, as we now realize, thanks to Professor Freud, the striving goes on, bringing what strange and partial satisfactions it may to the buried, thwarted and denied tendencies of his nature. From top to bottom of this scale of strivings we have to do with the same fundamental phenomenon. In the instances near the top, the more developed modes of mental life, involving the solving of a defined problem, the

thinking out of a plan, we all recognize the purposive nature of the striving. The goal, as envisaged, governs the movements of both mind and body.

In instances at the lower end of the scale, introspection or rather retrospection, inevitably fails to seize and report the thinking of the goal as distinct from the perceiving of the situation of the moment. Yet the continuity of the series justifies us in regarding its lower members as fundamentally of the same nature as its upper members and in applying the term "purposive" to them all alike.

Even in laboratory experiment, where the conditions are commonly so set as to reduce the striving factor to a dead level of uniformity and monotony, it refuses to be ignored forever; and so, after a generation of experimentation that ignored it, it is rediscovered and reinstalled in its place of fundamental importance, disguised under some such terminology as "determining tendency" or "motor set" or "conditioned reflex" or "prepotent reflex" or what not.

Under all three of the types of psychology we have noticed, this most vital, essential, distinctive aspect of human life escapes the psychologist. For it can not be described as either a sensation or a configuration (*Gestalt*). And it is not to be discerned by an inspection of the detailed movements of the limbs or of other bodily organs, no matter how exact.

Nor can it be restored or recovered in the psychology of parallel columns. It can be discerned in others only by sympathetic observation and interpretation of the course of their lives. If, under the influence of any metaphysical dogma or any supposed rule of method, you overlook it from the start, you can not introduce it into your otherwise completed picture of human nature, as an element to be added to and put alongside others already described.

It is too all-pervasive for such treatment. As well might the landscape artist, after painting a picture without atmosphere, attempt to add it by drawing a smear of paint across the whole. This is the difficulty found by students who have been brought up on the parallel-column psychology, as I know from instances of such students who have found difficulty with my frankly purposive "Outline of Psychology"; nor are such students helped to a truer view of human nature by those books on psychology which, after describing man after one or other of the three fashions we have noted, throw in perfunctorily as an afterthought a chapter on "The will." If striving has been ignored throughout the composition, "The will" can not be added to the picture as a finishing touch. Having learned to look upon man as a bundle of mechanical reflexes, a superior penny-in-the-slot machine, whose workings are

mysteriously accompanied by various "elements of consciousness," they can find no place in their completed picture for yet another element called "a purpose"; it refuses to fit in among the other blocks; there is no room for it, and, as they think, no need for it; and it seems to them quite an ambiguous, not to say shady and suspicious, character; at best it appears to them as a disturbing intruder.

But let the budding psychologist ponder some phase of human life that is dominated by some strong but thwarted desire. Let him consider the strange yet familiar case of Romeo seeking the Juliet who is forbidden to him. How this desire to see, to hear, to touch the loved one dominates his life, waking and sleeping! How it fevers his blood; wears him to a shadow; keeps him running to and fro, scheming, trying, hoping, desponding, exulting, despairing and always desiring! The desire governs all his thinking and acting; the most rooted habits and mental associations are as nothing in the course of this torrent of purposive activity, all directed to Nature's most imperative goal.

Can we accept any account, any description or explanation of human life which leaves out of the picture this all-important aspect that we call impulse, desire, striving towards a goal?

When we turn to the fields of applied psychology, the same truth stares us in the face. In every field we find that the most urgent practical problems are concerned with the striving aspect of human nature. The most fundamental task of the educator is to awaken an interest in and a desire for knowledge and self-development. The psychiatrist must study and redirect if possible the conflicting desires of his patient, his subconscious as well as his conscious motives and impulses.

The personnel manager is chiefly concerned with incentives, rewards, jealousies, rivalries, discontents, loyalties, ambitions and aspirations. The lawyer, the judge and the jurymen are primarily concerned to determine motives, intentions and responsibility. The politician, the economist and the moralist are, or should be, primarily concerned with relative values and the means to make real or actual the highest values of mankind by harmonizing and coordinating the conflicting motives of our social life.

In all these cases a psychology that ignores the all-pervading purposiveness of human life is of no use; for, if it is consistent, important words that are essential to the intelligent discussion of human affairs (such words as motive, intention, desire, will, responsibility, aspiration, ideal, striving, effort, interest) are of no meaning for it; or, if they are used, are used with a meaning so thin and so different from that of ordinary discourse, that profitable converse with the practical man is impossible.

I leave that large topic with these few words and pass to my third consideration in support of the policy of boldness. Thirty to forty years ago when I began to study science, considerable moral courage would have been required to insist upon the purposive nature of man. For at that time the great wave of scientific materialism was still but little past its climax. It was the day of Spencer and Huxley, of Clifford and Tyndal, of Lange and Weismann, of Verworn and Bain. The world and all the living things in it were presented to us with so much prestige and confidence, as one vast system of mechanistic determination, that one seemed to be placed before two acutely opposed alternatives: on the one hand, science and universal mechanism; on the other hand, humanism, religion, mysticism and superstition.

But to-day how different is the situation! Even at the date I speak of, a few great physicists warned us against regarding the principles of physical science as adequate to the interpretation of human life. And to-day those few voices have swelled to a chorus which even the deafest biologist can hardly ignore. Einstein and Eddington and Soddy and a score of others repeat the warnings of Maxwell and Kelvin and Poynting and Rayleigh. And the physical universe of eternal hard atoms and universal elastic ether, the realm of pure mechanics, has become a welter of entities and activities which change and develop and disappear like the figures of the kaleidoscope. The psychologist who would believe in the efficiency of human effort no longer needs to fling himself in vain against the problem—How can Mind deflect an atom from its predetermined course? For the atoms are gone; matter has resolved itself into energy, and what energy is no man can tell, beyond saying—it is the possibility of change, of further evolution.

In physiology the mechanistic confidence of the nineteenth century is fading away, as the complexity of the living organism is more fully realized, as its powers of compensation, self-regulation, reproduction and repair are more fully explored.

In general biology the mechanistic Neo-Darwinism is bankrupt before the problems of evolution, the origin of variations and mutations, the differentiation and specialization of instincts, the increasing rôle of intelligent adaptation, the predominance of mind in the later stages of the evolutionary process, the indications of purposive striving at even the lowest levels, the combination of marvellous persistency of type with indefinite plasticity which pervades the realm of life and which finds its only analogue in the steadfast purposive adaptive striving of a resolute personality.

All these considerations, I say, should encourage us to claim autonomy for psychology, the right to choose, shape and refine its

own fundamental conceptions. We should now easily find the courage to be anthropomorphic in describing man. Instead of accepting the abstract conceptions of physical science and attempting to build up from them a plausible mechanical dummy which shall stand for man in our science, let us frankly acknowledge that man is that thing in all the world with which we have the most intimate acquaintance. Let us begin by accepting him for what he seems to be, a thinking being that strives to attain the goals he desires, to realize his ideals, sometimes succeeding, often failing but always striving so long as he lives. Let us try to understand the history of these tendencies to strive as they are revealed in the individual and the species; to understand more nearly our knowing, our imagining, our recollecting, our judging and reasoning as they serve us in our strivings for the attainment of our goals.

As we progress with this task, let us cautiously extend the same principles of explanation to the animals of successively lower levels. And, when in this way we shall have gained some understanding of the life of the animalcule, we shall, perhaps, be able to begin to understand the physiology of the complex organism in its broader aspects. Instead of trying to illuminate human society by likening it to an animal mechanism, as was the fashion of the nineteenth century, we may find that we can profitably invert the process, that we can illuminate the complex organism by likening it to a well-organized harmonious human society, a society which can adjust itself to a thousand disturbances and can recover itself from grave disorders just because and in so far as each member, endowed with limited powers of adaptation, steadfastly strives always to achieve the goal prescribed by his own nature and by his active relations with all his fellow-citizens.

But here we shall be met again by the cry of the timid psychologist. "You are not scientific," he will say, "for you are disregarding the fundamental postulate of all science, namely, that all events are strictly determined, that mechanistic causation rules universally." To this we can only reply by exhorting him once more to have courage, assuring him that "Not all propositions made by all philosophers are true, neither does a proposition become true through being frequently repeated."

Let us be content to postpone metaphysics and to start out from two indisputable empirical facts: first, the fact that sometimes men create new things, such as great works of art and literature and new scientific formulae. Secondly, the fact that, when the normal man simply and strongly desires a certain end and perceives certain bodily movements to be means to that end, those movements follow upon that desire and that perception. Here are well-established

empirical generalizations from which we may confidently start out, refusing to be held up by questions at present insoluble, such as—How can consciousness deflect the path of a single molecule in my brain? Answers to such questions are quite unnecessary as foundations for purposive psychology. It is in the highest degree probable that as science progresses it will become clear that such insoluble questions have been wrongly stated and should never have been asked.

Let us not deny ourselves the right to build up a psychology that may be of use and value to our fellow-workers in the social sciences, because we can not at present answer the most difficult of all questions. The physicist is equally non-plussed if you ask him comparable questions, such as—how does one molecule attract or repel another? What is the nature of chemical affinity? What is electricity? But he does not suspend his researches because his fundamental conceptions and assumptions are disputable and disputed, nor does he turn to some other branch of science in order to borrow from it others that have more prestige. Let us follow his example.

Let us gather our facts of human nature by objective and by introspective observation. Let us make our empirical generalizations and correlations of these facts, building up our own science in our own way. Let us boldly affirm that, just as the physical sciences do not proceed deductively from any system of exact abstract propositions, so also psychology, the most concrete of the sciences, is not required by any higher authority to accept or formulate any abstract propositions as an unchanging deductive basis.

It may be that eventually men of science will agree that there are in the universe two ultimately different kinds of process, the mechanistic and the purposive, the strictly determined and the creative, the physical and the mental. Or it may be that, eventually one of these may be shown to be merely an appearance of the other, an appearance due to the present limitations and imperfections of our understanding. At present we can not decide this issue.

But, if I attempt to guess at the future development of science, I incline to follow the lead of the most powerful intellects of all ages, and to predict that, if such resolution of the two types of process into one shall ever be achieved, the purposive type that we regard as the expression of mind will be found to be more real than the other.

THE DATE-PALM IN ANTIQUITY

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"HONOR your paternal aunt, the date-palm," the prophet Muhammad enjoined his followers. "I call it your paternal aunt because it was created out of the earth left over after the creation of Adam (on whom be peace)."

Whether this account of the origin of *Phoenix dactylifera* Linn. be accurate in detail or not, it is certain that at the dawn of history the date-palm is found established and cultivated in the subtropical zone from Western India to the Atlantic Ocean, and that since the beginning of written records it has been prominent as a means of sustenance, a source of material for manufactures, a fount of beverages and an object of worship for many peoples.

Some millions of years ago, the genus not only extended into Northern Europe, but occurred in North America as well. It would be difficult, on the basis of the material available, to relate the various fossil forms of Phoenix-like palms to any one modern species of Phoenix rather than another. They therefore throw little light on the much debated question of the locality in which the cultivated date-palm first appeared. It has been accredited by one student or another to almost every part of its present range. So far as one may safely speculate on the data furnished by the present distribution of the genus, it appears to me that the reasoning of O. Beccari is sound.

In the first place, he says, the home of the entire genus must be located, and he believes this to be India. While the distribution of known fossil remains does not bear out this conclusion, it may be replied that the fossils of the orient have been little studied, compared with those of Europe, and, if search were made, abundant evidence might be found of Phoenix in the orient. In any event, the distribution of the existing species, and their affinities, may be fairly interpreted to support the oriental origin of the genus, as against an African, European or American origin.

Next, the home of the date-palm must be more definitely located by a consideration of its characteristics. It is a plant that thrives best in subtropical regions with scanty rains or none at all; yet it demands abundant and constant moisture about its roots. The seeds not only require wet soil in which to germinate, but the cotyledon has no less than four well-marked features adapting it

to resist excessive moisture, and the roots of the seedling possess as many similar peculiarities, according to G. Firtsch. These features can be reasonably explained as showing that the seedling is adapted to grow in water-logged soil. Moreover, the species is remarkably tolerant of salt water and alkalis.

Dr. Beccari interprets these facts, plausibly enough, to mean that the date-palm originated in a country where the air was hot and dry but the ground sodden with salt water. Where can these conditions be met so well as on a subtropical seacoast?

If India be accepted as the home of the genus, then this particular species must have taken its origin somewhere on the margin of the generic home, for the greater part of India will not meet the requirements above laid down. In extreme northwestern India, and beyond, along the shores of the Persian Gulf, is a region that exactly fills the specifications. Here, then, the ancestral home of the date-palm may be placed with some assurance.

But speculation about something that happened so long ago is more interesting than certain. It is certain that the date-palm is not to be found wild at the present time on the shores of the Persian Gulf, or anywhere else. The wild palms that have been reported from various parts of the world must be regarded as escaped or naturalized. The fruit is so easily transported and the seeds, thrown aside by a traveler or carried long distances to be dropped in the excreta of animals, germinate so readily that it is easy to account for the presence of the palm in even the most remote spot. It can grow only near water, and as a water supply in the desert is prized above everything else, and certain to be visited from time to time, no matter how remote from civilization, it can rarely happen that any palm is left entirely to itself for many years. All the uncultivated palms of which I have ever heard, in the most remote fastnesses of Arabia or the Sahara, are visited at least in the fall by nomads who gather the ripe dates.

Like many other cultivated plants and domesticated animals, then, the date-palm to-day represents a human product, long removed from and somewhat altered from its ancestral condition, whatever that may have been.

From India I have found few records indicating the importance of the date-palm at an early period, although the Sanskrit language is well supplied with indigenous names for it. The species is naturalized in Sindh, where there are two local legends regarding its origin: (1) That dates formed part of the commissariat of Alexander the Great, when he invaded the country in 327 B. C., and that the present groves sprang from seeds thrown away by his soldiers, and (2) that the fruit was introduced by the Arab con-

querors of Multan and Sindh in the seventh century A. D. Of course neither of these legends is to be taken seriously: It can hardly be doubted that the date-palm has been at home in northwestern India since prehistoric times, although it has never been brought to a high state of culture there.

The oldest written records are found in Babylonia. Scholars are now generally agreed that no really historical settlement in the plain of the Tigris and Euphrates rivers can be traced with certainty much before 5000 B. C., but it is likely that the palm was cultivated there for several thousand years previously. The first historical records, which do not go back much farther than 4000 B. C., show civilization already far advanced.

Obviously, the cultivation of the palm can not be dated very far back in the Tigris-Euphrates delta, where it now finds its greatest commercial development, for the reason that this alluvium itself is relatively recent, having been laid down not earlier than 10000 B. C. in all probability. The culture of the palm may have been brought into the delta from Arabia; or from northern Mesopotamia, where A. T. Clay thinks the ancestors of the Babylonians learned the art of irrigation, or it may have come in from the gulf coast of Persia. I have found little record of it in the antiquity of the last-named country. But no matter whence it came, it is a safe inference that it had already begun to play an important part in the life of the people who cultivated it.

Dr. Beccari has pointed out that in at least four respects the palm had a peculiarly intimate relation to the primitive date growers:

(1) It produced a large supply of the best possible food, easily stored or transported, and therefore adapted to give its possessors a notable advantage over their neighbors.

(2) It furnished a rich source of material for building and home industry, to the extent of satisfying a large part of the requirements of its owners. Strabo refers to an old Persian hymn which enumerated 360 different uses of the palm.

(3) It furnished an intoxicating beverage, called in cuneiform inscriptions "the Drink of Life." The way in which this could have come into use is interestingly conjectured. "That primitive man could at a very early period discover the manner of obtaining a fermentable liquor from the date-palm is easily understood," Dr. Beccari remarks. "When he learned that by cutting out the terminal bud of the palm he obtained a delicious food, he also found that as a result of that operation a sweetish liquid flowed abundantly from the wound. Nothing more natural, in a country where water is scarce, than that this liquid should have been caught

in some kind of a receptacle and used for drinking. But in the meantime the liquor fermented: and thus, perchance, earlier than the juice of the grape, man may have learned the method of making alcohol, and felt the effects of its inebriating power."

Dr. Beccari might well have emphasized even more strongly the tremendous importance this discovery must have had as an agent of natural selection of humankind. While palm wine is not to be compared, in alcoholic content, with distilled liquors, it yet contains enough alcohol to be dangerous, when fermented. The French government had to prohibit its manufacture in Algeria, partly because the bibulous Berbers were destroying their plantations in order to gratify their craving for stimulants, but largely because the beverage led to incessant breaches of the peace. The influence of alcohol in injuring the human body is to-day well recognized: yet most of the people now exposed to it are the product of many centuries of natural selection, when the least resistant drank themselves to death and only the stronger survived to become the ancestors of the present generation. The havoc that might have been wrought by palm wine, when first discovered and used by a people who had never undergone any selection against alcohol, can only be imagined by remembering how the American Indian has fared under similar circumstances.

(4) Added to its value as a producer of food, drink and shelter, the date-palm possesses another element of intense interest to the primitive mind, in the separation of its sexes on different plants. The mystery of reproduction always appeals strongly to the imagination of primitive people—as indeed it does in somewhat different ways to more sophisticated populations—and here was a particularly striking case, where the process of fecundation could be watched or even carried out by the agency of man, and where the difference of result, as the female was or was not pollinated, was marked. Moreover, the subsequent development of the embryo was more visible than it is in the higher animals. The useful date-palm, already revered as a storehouse of delicious food and a fountain of the drink of life, came to symbolize the creative force of nature, and to be in some cases the object as well as the symbol of worship. It gradually became identified (as has been skilfully shown by George A. Barton) with the primitive Semitic goddess, later personified as Ishtar or Astarte, who particularly embodied nature's creative forces.

In short, the paternal aunt had made her way into the Pantheon.

The earliest records of the palm cult show it centered at Eridu, only a few miles from that Ur of the Chaldees (Mughair of modern maps) whence Abram migrated to Palestine; and now 90 miles

from the head of the Persian Gulf. It was then a seaport, however, and calculations of the rate of silt deposition indicate that this must have been about 7000 B. C. It may be that this was the first station occupied by the invading Semites, coming north out of Arabia, and it is a plausible conjecture that they stopped here because they found their old friend, the date-palm, already in possession of the ground.

Here, at a somewhat later date, was a famous oracle tree, known as the Tree of Life, whose position in a garden near the town marked the center of the world. This tree was a date-palm. A fragment of an old hymn has been preserved, which tells something of this institution:

> In Eridu a palm-stem grew overshadowing: in a holy place did it become green;
> its root was of bright lapis lazuli which stretched toward the deep: [before] the god Ea was its growth in Eridu, teeming with fertility:
> its seat was the [central] place of the earth; its foliage was the couch of Zikum, the [primeval] mother.
> Into the heart of the holy house which spread its shade like a forest hath no man entered.
> [There is the Home] of the mighty mother who passes across the sky.
> [In] the midst of it was the god Tammuz.

As the translator, A. H. Sayce, explains, "The sacred tree whose branches reached the heaven while its roots were nourished by the primeval deep was the tree which supported the world. It was emphatically a Tree of Life and is accordingly represented time after time on the monuments of Babylonia and Assyria."

The palm cult rapidly became widespread and organized. It extended gradually northward, reaching Phoenicia and Syria; residents of the former region carried it to the western Mediterranean, as will be described later. In all these regions the Tree of Life, the date-palm, became a conventional factor in decorative art, reaching its greatest vogue, perhaps in the kingdom of Assyria about the ninth century before the Christian era, when the huge palaces of Nimrod (Nineveh) were constructed, in which the palm and the palm god figure at every turn.

In general, the sacred palm was depicted in the interior decoration of temples, on city gates, royal vestments, seal cylinders and anywhere else that the ingenuity of the artist could work it in. Early representations show the palm god as a human figure with palm leaves attached to her shoulders like wings; later these leaves were conventionalized into feathers, as being more suitable for a member of the animal kingdom, and the god appears with a pair of avian wings. The paternal aunt is now a full-fledged divinity.

The plain of the Tigris and Euphrates rivers, where the worship of the palm originated, was known to its early dwellers as Edin, and it was long ago suggested that the Biblical legend of the Garden of Eden, with its sacred trees, is but a version of Babylonian legends concerning the palm god. "The garden with the Tree of Life in the midst was planted 'in Eden, eastward,' for such is the correct rendering of the Hebrew text," declares Dr. Sayce, "and not 'eastward in Eden,' as the Authorized Version has it. Not only the garden, but Eden also, lay to the east of the land where the writer lived. The garden stood hard by Eridu, 'the good city,' and thus in the very region where the salt 'river' of the Persian Gulf was divided into its four heads," mentioned in *Genesis* ii, 10–14. The Tree of Knowledge of Good and Evil, mentioned more prominently in the Biblical account, must be regarded as derived from the interpolation of a second legend. Whatever the latter tree may have been, it is fairly clear that the Tree of Life represented the date-palm; and this supposition is distinctly confirmed by the Apocrypha. In the oldest portion of the Ethiopian Book of Enoch (Chapter 24) it is related that the prophet visited Paradise and found the Tree of Life itself—and it was a date-palm.

The sacred character of the palm involved various corollaries: for instance, among the ancient Assyrians it was bad luck to walk between two palms growing close together; while dates were tabu at times and to eat them on forbidden days was thought to bring on ophthalmia.

Presumably the dates grown by early cultivators were inferior berries with large seeds and little flesh, like the fruit of many seedling palms to-day, or like that of the wild Indian species, *P. sylvestris* Roxbg. But amelioration by the selection of superior seedlings and propagation of them by offshoots took place before the beginning of history. By the time of Hammurabi (about 1958–1916 B. C.), palm-growing was established on a sound basis as one of the principal agricultural occupations of Babylonia. The sixtieth paragraph of that monarch's famous code of laws provides that, if a man lease his garden to another to plant as an orchard, he shall let it without rent for four years, but in the fifth year the owner shall have half the fruit. There are several contracts of the period of Hammurabi which relate to orchards, all of which mention dates as the only fruit crop. The natural inference is that a Babylonian orchard was a date orchard, and that planting an orchard meant bringing palms to bearing. Four years, then, was the time allowed for this—a limit that calls for skilful propagation. Indeed, if the Babylonians could get a crop of dates in the fifth

year, they did better than their present-day successors in that region.

In the archives of the temple library at Nippur, dating not many centuries after Hammurabi, Edward Chiera tells me that he has found a list of some 20 distinct horticultural varieties of date-palm, with particulars as to the yield of each one. Such a status argues a great antiquity for the culture.

In Egypt the palm likewise seems to have existed from prehistoric times and may have been found there by the ancestors of the old Egyptians, when they themselves migrated into the Nile valley. Presumably it was cultivated by the pre-Egyptian population, and its fruit already improved by selection, for its hieroglyphic name, BNR or BNRT, is held to be an Egyptian, not a borrowed, word; whereas, if the Egyptians had brought the palm from southern Arabia, as most students have supposed, they would be likely to have brought a Semitic name with it. The name is said to mean "sweet," and could hardly have been given to a wild representative of the species—it points rather to a good fruit, the product of centuries of cultivation.

But though the culture here, as in Babylonia, goes back at least to Neolithic times, it would be erroneous to suppose that its antiquity, in the Nile delta at least, is immense, for this alluvium was probably deposited no earlier than that of the Tigris-Euphrates, or say 10000 B. C.

The first mention of the palm in Egypt that has yet been found, according to Wilfred H. Schoff, deals not with the fruit but with wine made from the sap—the "Drink of Life" of old Babylonia—which is mentioned as an Egyptian product shipped up the Nile to Negro Land, in an inscription of the reign of Mernere in the sixth dynasty, about 2600 B. C. Thereafter the palm seems to hold front rank among the fruit trees of the country, although it does not appear frequently on the monuments until the twelfth dynasty, and at no time figures so conspicuously as in Mesopotamia. This difference, which Egyptologists have generally held to indicate a late introduction of the palm, may be explained more plausibly as showing that in Egypt the palm was merely a horticultural product: its prominence in Babylonia was not merely horticultural but, as I have pointed out, religious.

The first reference to dates as food which Mr. Schoff has found is in an Abydos inscription of Khenzer, seventeenth century B. C. In the eighteenth dynasty it springs into greater prominence, particularly in the Thebaid, but the few gardens specifically described are small: that of Anna held 170 palms, while that of a military chieftain contemporary with Amenhotep II contained 93—less

than an acre of ground, and probably therefore a mere gentleman's park, rather than a commercial plantation. Much of the Egyptian supply of dates was then secured (so H. F. Lutz tells me) from the western oases, just as it is to-day. At no time, either ancient or modern, has the cultivation of this tree attained on the Nile either the importance or the perfection that it has in Babylonia, yet it has always played a prominent part in the commerce and industry of the country. In the reign of Rameses III (twelfth century B. C.) the papyrus Harris records as "offerings for new feasts" dates, 65,480 measures, with 3,100 cut leaves—the latter for decoration; again, 241,500 measures; and as "offerings to the Nile God," dried dates, 11,871 measures, 1,396 jars; dates, 2,396 measures. It is clear that the gods, or their human assistants, had a taste for the fruit of the palm.

In Syria the palm has long been grown to a limited extent, but the climate is ill-suited to its commercial cultivation, and its early importance was rather religious than horticultural. The palm cult, probably carried northward from Babylonia, found no lack of adherents among the Phoenicians and Syrians. It is frequently to be detected among the heathen gods to whom the Old Testament prophets animadvert. None of these objects of superstition is better known, by name at least, than Baal, who was originally the god of unirrigated land as contrasted with Ishtar (Astarte), the goddess of irrigated soil and fertility. Baal is an old Semitic word which, even to-day in Arabic, means an unirrigated palm; and its metamorphosis into the execrated divinity of the idolaters is traced fascinatingly by Dr. Barton.

The cult even insinuated itself among the Chosen People. The prophetess Deborah sat under a palm, which inferentially helped her inspiration. The palm formed one of the chief motifs in the decoration of Solomon's temple—indeed, the very origin of columnar architecture is ascribed to the Babylonian use of the trunks of date-palms as building material. Thus in respect of the palm cult, as in many other respects, the religious reformers of ancient Judea were unable to keep their compatriots wholly uncontaminated by the sins of the surrounding heathen.

Phoenician traders had carried the cult to all parts of the Mediterranean as early as the Neolithic period. In graves of this age in Spain and Portugal clear evidence of it has been found. While the palm was well established in these countries before the commencement of the Christian era and may have grown there several thousand years before, its fruit was inferior, as it is to-day, and it seems unlikely that it could have become an object of veneration, save as the cult was imported by Levantine vessels coming for tin.

The same traders had established the cult in North Africa long before they founded their colonies, of which Carthage is the most famous. Two British archeologists, C. F. and L. Grant, remark on this point:

> Even the popularity of the Seal of Solomon pales before that of the palm, or the palm leaf, as a symbol in North Africa. It may be safely said that there is hardly any building upon which it is not somewhere to be found, in some form or other. . . . The palm appears upon nearly all the Carthaginian stelae, especially upon those dedicated to the great African god Hammon, but it has also been found upon objects dating from a civilization earlier than the Punic. M. Ohnefalsch-Richter thinks that it is a Mycenean symbol. It was certainly an ancient Libyan one before the foundation of Carthage [about 880 B. C.]. The palm was also the great Libyan totem.

That the Greeks obtained their knowledge of the palm from the same source is evident from the name they gave it—Phoenix, the tree of the Phoenicians. As the symbol of that country it is found figured on the Phoenician and, later, the Carthaginian coins struck in Sicily. The invasion of oriental cults brought with it the use of palm leaves as symbols of victory at the great festivals—an imitation, perhaps, of their use by the Jews at their Feast of the Tabernacles, originally a feast of rejoicing at the time of the date harvest. This usage has not yet been dropped from the language: the classically-read man still agrees, *Palmam qui meruit ferat.*

Traces of the palm in Greek and Roman civilization have been diligently gathered by Victor Hehn. It is not mentioned in the Iliad, but appears in the Odyssey, particularly in the well-known scene where the far-traveled Ulysses approaches Nausicaa on the strand and flatteringly beseeches her assistance:

> Never, I never viewed till this blest hour
> Such finished grace! I gaze, and I adore!
> Thus seems the palm, with stately honors crowned
> By Phoebus' altars; thus o'erlooks the ground,
> The pride of Delos. (By the Delian coast
> I voyaged, leader of a warrior host;
> But ah! how changed! from thence my sorrow flows;
> Oh, fatal voyage, sum of all my woes!)
> Raptured I stood, for earth ne'er knew to bear
> A plant so stately, or a nymph so fair!

His address is quite in the oriental style, for the Beloved is told, in the so-called Song of Solomon, "This thy stature is like to a palm," a figure that can be matched in Arabic poetry at any time up to the present; while daughters of Palestinian kings bore the name Tamar, date-palm.

The palm near the temple of Phoebus in Delos, to which Ulysses refers, was one of the most famous in classical history: at its foot,

clasping the trunk with her arms, Leta was fabled to have given birth to her son Apollo. The identical tree was shown to the credulous as late as the time of Cicero and Pliny, both of whom speak of it. Much evidence has been brought together by L. Siret and others to show that Apollo was originally an oriental palm-god.

Early Italian references to the palm probably refer to the native dwarf genus, *Chamerops humilis* L., the only representative of the order that is found wild in Europe. But in the early days of the city the *tunica palmata*, adopted like other badges of magisterial pomp from the Etruscans, was embroidered with leaves of the oriental palm. The legend that Rhea Silvia, mother of Romulus and Remus, saw in a dream two palms growing before the altar of Vesta, one of which shaded the whole earth and touched the sky with its crown of leaves, is evidently of late invention, imitated from the vine that, springing from the lap of Mandane, daughter of Astyages, grew till it covered all Asia; or from the olive tree seen by Xerxes in a dream, which spread over the entire earth; and these in turn perhaps borrowed from the Tree of Life in Ea's sanctuary at Eridu, which later found its way with Adam and Eve into the Garden of Eden.

But as early as 291 B. C. evidence of the existence of the date-palm at Antium is to be derived from the miracle recorded concerning the snake of Aesculapius, fetched from Epidauros by the Romans during a plague. At this port the snake escaped from the ship and twined itself around a tall palm on shore. Mention by later writers suggests that the palm may frequently have appeared in southern Italy as an accompaniment of temples dedicated to Apollo; but the first knowledge of it is due to the Phoenicians, not the Greeks, if Dr. Hehn's conjecture is correct that the Roman name palma is a corruption of the Hebrew tamar.

By the beginning of the empire the date-palm is so well known that the elder Pliny is able to give an extended account of it, from Spain eastward to Persia, and to enumerate many different varieties —which seem, however, to be trade names rather than horticultural designations. The value of the fruit was not ignored, for Pliny declares, "Indeed, when in a fresh state, they are so remarkably luscious that there would be no end of eating them, were it not for fear of the dangerous consequences that would be certain to ensue."

It is not to be supposed, however, that there was any important export of this fruit from the orient to Europe, for, as W. H. Schoff has pointed out to me, freight rates would be too high to make such a commerce possible. There may have been some trade in date wine, a more valuable commodity in proportion to its weight; but this would have been as an exotic curiosity, not as a staple beverage.

The *Periplus of the Erythrean Sea* shows that there was a large export of dates from eastern Arabia to the west coast of India, about 80 A. D., and there may have been some overland exportation from Persia eastward. Dates were known in China within three or four centuries after the beginning of the Christian era, if not earlier.

Little is known of the cultivation of the palm in early Arabia, although there is some evidence of the religious cult there. Pere Anastase-Marie de St. Elie, O.C., of Baghdad, has called my attention to a date-palm in Najran which was treated in all respects as a god: each year the populace celebrated the feast of this deity by attaching new clothes and jewels to the palm. The heathen divinity al-Uzza, one of the objects of Muhammad's scorn, had his residence in a grove of palms near Nakhleh—a name which itself means date-palm. But from the time of the prophet—say about 600 A. D.—the palm comes into the light, largely because he happened to take up his residence in a town (Medina) which was and still is the most important center of date-growing in the northwestern part of the peninsula. The zeal of the traditionists has collected, in an incidental way, much valuable information about dates. Some of the legendary lore which is thus related to Muhammad is doubtless of earlier origin, and strongly suggests the influence of the venerable cult.

Fresh dates were, with melons, the prophet's favorite food, and during his period of poverty, for months at a time he had little to eat except "the two blacks," *i.e.*, dates and water. It may have been partly to put the best construction on an unpleasant situation that he eulogized the palm so frequently. Of the 26 references to palms, or dates, in the Koran, 16 mention them as evidence of Allah's bounty. The others are mostly casual.

"How many a very tall palm will there be in Paradise!" he once exclaimed. Some of the generally accepted traditional lore is thus summarized by Qazwini:

> The blessed date-palm is found only in countries where Islam is the prevailing religion. The Prophet, in speaking of it, said, "Honor the palm, which is your paternal aunt"; and he gave it this name because it was made from the remains of the earth out of which Adam was created. The date-palm bears a striking resemblance to Man, in the beauty of its erect and lofty stature, its division into two distinct sexes, male and female, and the property which is peculiar to it of being fecundated by a sort of copulation. If its head is cut off, it dies. Its [male or pollen-bearing] flowers have an extraordinary spermatic odor, and are enclosed in a case similar to the sac in which the fetus is contained, among animals. If an accident happens to the marrow-like substance at its summit [*i.e.*, the terminal bud] the palm dies just as we see a man die when his skull is severely injured. Like the members of a

man, the leaves which are cut off never grow again; and the mass of fiber in which the palm is surrounded offers an analogy to the hairs which cover the human body.

In another tradition Muhammad says, "The virtuous man is like a palm: he stands erect before his Lord; in every action he follows the impulse received from above; and his whole life is devoted to the welfare of his fellow-creatures."

According to Arab historians, the germ pore on the back of the seed is due to Solomon the son of David (on both of whom be peace), who impressed it with his famous seal ring, of mingled iron and brass, inscribed with the secret name of God, by virtue of which he possessed control of all animal life and the spirit world. The medieval Christians of the orient, jealous of Muslim monopolization of the virtues of this important tree, attempted to divert some of the tradition to more worthy channels: according to their account the germ pore, which is merely a small, circular depression, is due to the fact that when Mary was eating dates under the palm, after the birth of Jesus, she exclaimed, "O, how sweet they are!" the interjection remaining indelibly printed on the seed.

Association of the palm with the birth of Jesus, like that with the birth of Apollo, represents a notable and in this case a surprisingly late outcropping of the hoary palm cult. It is found in the Christian Apocrypha, and was given wider circulation by Muhammad in the Koran. Muslim commentators have embellished it, to make the most of this miracle; I quote the version of Tabari, which is an embroidery on the shorter text of the Koran:

When the time of her delivery was near at hand, Mary was ashamed to be seen by Zachariah and by the numerous temple servants, so she went out alone, leaving the temple and city behind her. Having walked some distance, she was overcome by those pains which women experience at the moment of childbirth. . . . In the distance she perceived a tree. It was a dried-up date-palm, whose leaves had fallen and whose branches had broken. Mary turned her steps toward this tree; the pains did not allow her to go any further; she sat down under that tree, as it is said in the Koran: "The pains of childbirth came upon her near the trunk of a palm." When her delivery was completed, and she had brought Jesus into the world, the pains and shame caused her to utter these words: "Would to God that I had died before this, and become a thing forgotten." The Koran continues: "A voice below her cried out, 'Be not grieved; now hath God provided a rivulet under thee' ". When Jesus first saw the light of day under this palm trunk, there was in that locality no rivulet, nor water of any kind. God caused a spring to gush forth from that place, and the water flowed along the ground, in order that with this water Mary might bathe herself and Jesus. Then the voice said to her: "Do thou shake the trunk of the palm, and it shall let fall ripe dates upon thee." Mary shook the tree, and at that instant dates appeared, ripened and dropped. She ate some of them, and her body regained

its strength. The date is a hot fruit; when it is given to a woman weakened by childbirth, it restores her strength. This is the reason why a woman newly delivered of a child is given dates or a cake made from dates. From God himself was this usage learnt.

An early tradition put the birth in Egypt, near the town of Ahnas: Kaab al-Ahbar declares he saw the identical palm there, and Makrizi bears witness to the same effect, while Ibn Haukal, in describing the town of Akhmim, Egypt, relates, "It is said that the date-palm, of whose fruit Mary ate, has been placed in the dome or vault which is here, and is held in high respect." Ibn Batutah, one of the most sober-minded of Muslim travelers, avers that he saw "traces" of it in the church at Bethlehem.

Because of this legend, Muslims sometimes refer to Jesus by the name of Dhu al-Nakhleh, "the date-palm man."

With the transfer of the caliphate to Baghdad in 750 A. D., literary emphasis of the palm again shifts to the place of its origin, but the mists of mythology begin to clear away. The paternal aunt slowly ceases to be a goddess, and remains merely a very useful and much respected member of the family.

A DESERT TRAGEDY

A DESERT TRAGEDY

By Dr. DAVID STARR JORDAN

STANFORD UNIVERSITY

In the little drama I shall set forth the actors are two: First, a desert bob-cat, *Lynx eremicus*; and, second, a great horned owl, *Bubo virginianus*. The scene is laid on a cliff in the desert in the western part of Fresno County, California; the hour, towards sunset, in the summer of 1901.

The wildcat is watching for jack rabbits from the top of the cliff, his colors, gray and rusty, matching the color of the rocks. The same colors are borne by the jack rabbit, the prey of the owl, and this animal the great owl unwittingly takes him to be. She swoops down on him with her great beak and long sharp claws. Both are surprised, and each is a match for the other. The wildcat has by far the stronger jaws, the bird has the advantage in his claws, and in the wings which should afford means of escape if the attack went wrong.

Whatever the theoretical handicap on either side, the two were equal in fact. The cat seized the bird's great wing at the wrist joint, crunching the bones and rendering the wing useless. The owl thrust its long, sharp claws through the muscle of the cat's fore-leg rendering the cat helpless to move. There was no help to either side, "no referee to call a foul." So they struggled through the night, at last falling from the cliff stunned and dying. There they lay, locked in fatal embrace for a month or two, their flesh drying in the desert sun.

At last Mr. Edwin R. Graham, a prospector from Hanford, found them there, and sent them up to Stanford University. There a photograph of the pair was taken by Charles F. Lummis, of Los Angeles, through whose courtesy it is reproduced here. The story of a "Duel in the Desert" was published by him in his inimitable journal, *Out West*, in January, 1902.

MAJOR-GENERAL SIR DAVID BRUCE

President of the British Association for the Advancement of Science which met in Toronto from August 6 to 14. Sir David Bruce's presidential address was on the prevention of disease, to which subject he has made distinguished contributions.

THE PROGRESS OF SCIENCE

By Dr. EDWIN E. SLOSSON

SCIENCE SERVICE, WASHINGTON

VITAMINS

THE vitamins, infinitesimal but indispensable ingredients found in our food, formed the topic of one of the most exciting sessions of the British Association for the Advancement of Science at its Toronto meeting. "Found in our food" is the wrong phrasing, for the vitamins are in our food but not yet found, although the chemists of all countries are hunting for them as hard as they can. But it is hard to find something when you can not see it and do not know what to look for. A blind man could easier find a needle in a haystack, yet the search seems to be nearing success. Professor Walter A. Eddy, of Teachers College, Columbia University, was able to exhibit a small sample of what appears to be a vitamin in a form sufficiently pure to be crystallized and analyzed. The analysis indicates that its molecule is composed of five atoms of carbon, eleven of hydrogen, three of oxygen and one of nitrogen. The process of extraction is a tedious and delicate one. Starting with six pounds of fresh yeast, he thinks himself lucky in being able to get out seventy milligrams of the product in the end. But this is so potent that five hundredths of one milligram per day added to the ration of a young rat on a deficient diet will restore it to health and start it growing. The same substance has a stimulating effect on the growth of the yeast plant. Such a yeast promoter is known as "bios," but whether his product is a known vitamin, or whether it is essential to the growth of mammals or even to all kinds of yeast, are questions on which Professor Eddy is not yet ready to commit himself.

Professor Lash Miller, of the University of Toronto, who has been working for many years on bios, has separated it into two different fractions. These are present in varying proportions in many vegetables, and he has found tea the most convenient source for its preparation in quantity. Both kinds of bios have to be present to produce the full effect in the rapid multiplication of yeast cells.

The vitamins may turn out to be the clue, not only to the cause of many obscure diseases, but also to some of the problems of history. What is called race suicide or class suicide may be due in part to an accidental dietary deficiency for Professor Herbert M. Evans, of the University of California, showed that besides the vitamins necessary for health and growth there is another that he provisionally calls "Vitamin X," which is essential for reproduction. Rats living on food devoid of X will grow up and thrive and live apparently normal lives, but the male can not generate, and the females can not bring forth young. Fertility can generally be restored by adding to the ration some food containing the lacking vitamin or a few drops of the concentrated extract. Wheat germs, lettuce, egg yolk, liver, vegetable oils, and butter, especially butter from alfalfa-fed cows, are among the foods containing Vitamin X, but it is absent from skimmed milk, sugar, white bread and cod-liver oil, although cod-liver oil

is very rich in the vitamins that promote growth and prevent rickets. A mother may transmit a limited supply of X to her offspring, but not enough to last through life. Sterile rats may be cured by feeding on the flesh of normal rats. Professor Evans finds he has been able to extract X from wheat germ in quantity and to obtain it as an oil of high potency, but has not yet obtained it pure enough to determine its chemical composition. That a shortage of the fat-soluble Vitamin A may increase the liability to lung trouble was shown by the experiments reported by Professor H. C. Sherman, of Columbia University. Rats which had an insufficient supply of this vitamin in an otherwise adequate diet "showed a striking tendency to break down with lung disease at an age corresponding to that at which pulmonary tuberculosis so often develops in young men and women. The bacillus involved is different, but the close parallelism in susceptibility of lung tissue to infection at this stage of the life history appears very significant, especially in view of the further observation that the fat-soluble vitamin content of the lung tissue varies with that of the food." Of two similar sets of rats, kept on identical diet, except that one was deficient in fat-soluble A, the females on the complete ration bore an average of twenty-eight young and reared sixteen each, while those on the diet low in this vitamin bore an average of two young and reared none whatever, and lived only half as long. Both batches had Evans's Vitamin X, so evidently Vitamin A is also necessary for reproduction.

Butter is rich in Vitamin A and cod-liver oil richest of all, so the practice of prescribing these fats in case of consumption is substantiated by recent researches. Carrots are much richer in this vitamin than potatoes or turnips, spinach is richer than lettuce, and green celery than the bleached leaves.

CUBICAL CULTIVATION

THE city man has the advantage of the countryman in that he can expand his business perpendicularly. Our city "squares" have become cubes, but the farmer lives in Flatland like all his ancestors. When he buys an acre of land, he only gets an acre area. But when the city man buys an acre, he piles story on story till he gets ten or twenty acres of floor space out of it. The forester, it is true, can raise his foliage factory to the height of a house, but then the shaded space beneath becomes useless.

But in part of the world these limitations on life do not apply, and this is the greater part of the earth's surface; in fact, seventy-one per cent. of it. For water, unlike soil, is transparent, and the sunlight, which supplies the vital energy to all vegetation, can penetrate the ocean to the depth of a thousand feet or more, which beats the sky-scraper by far. Think of having a garden measuring five hundred feet by five hundred by five hundred feet full of growing vegetation! And what a pasture that would make for stock able to feed off every cubic foot of it!

Such garden plots and such pastures there are in the sea, but so far man has done nothing in the way of cultivating them. His control stops with the shore. The modern man merely hunts in the ocean as his ancestors did in the forest, unsystematically, wastefully, often disastrously, destroying what he desires.

Man has hardly yet begun to consider the conservation of the wild life of the sea, still less its cultivation. These are questions for the future.

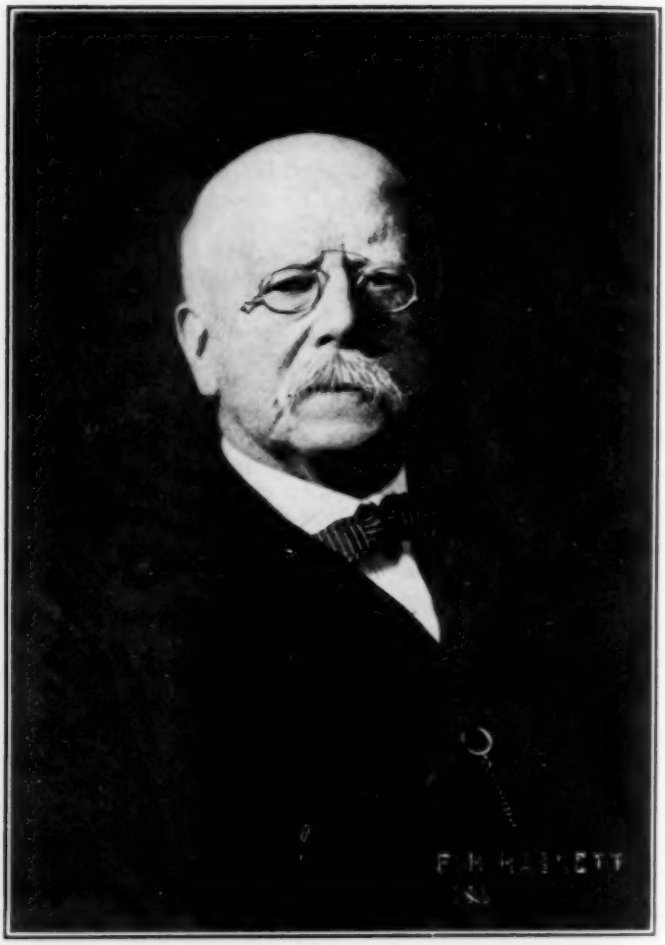
But this future is rapidly coming, for each year the fishing craft have to go farther and farther out to sea and use more power in getting their haul. British trawlers can now get only about half their fish from the North Sea, and they are forced to trawl the banks of the Faroe Islands and Iceland. It takes eight to ten tons of coal to catch a ton of fish and the trawler gets on the average only about five cents a pound for it at the port. Before the war a British steam trawler of 125 feet in length could be run profitably for less than $20,000 a year. To-day it costs some $50,000. Coal and nets are twice the pre-war price.

The herring fishing of Great Britain has been hardest hit by the war. In 1914 the industry was worth nearly $25,000,000 a year and employed some 60,000 people. More than 2,250,000 barrels of pickled herring were exported. But seventy per cent. of these exports went to Russia and twenty per cent. to the Germans, and now the Russians have locked their doors and the Germans have scant money to pay. Poland and the United States have curtailed the market by putting duties on imported herring. Consequently, British fishers are asking government aid and protection against foreign fish, a sad situation for an industry that has maintained its proud independence and supremacy for five hundred years.

In 1424 the herring migrated in mass from the Baltic to the North Sea for some mysterious reason, and this sudden shift of the shoals built up the British seapower and made Germany and Russia dependent upon British fishermen. We may hope that eventually the financial embarrassments and the present impediments to commerce may be removed or readjusted, but until we learn more about ocean life we shall not be able to make full use of the harvests of the sea. We have taken the first step when we realize that there is a "reason" for such a migration, even though we must admit that it remains "mysterious." If we open the stomach of a herring, we may find it contains as many as 60,000 copepods. The copepods are primitive crustaceans that look like tiny shrimps. They feed on the minute plant forms found in the thick sea-soup, called "plankton," that is scooped up in a tow net. There are 2,500 diatoms to one copepod. Now the diatoms are extremely sensitive to changes in the composition of the sea water, its alkalinity and the percentage of salt and lime it contains. And, of course, the growth of all such vegetation depends upon the amount of sunshine that falls upon the sea and the depth to which it penetrates. The diatoms swarm when the temperature gets right. With them come the copepods that browse upon them. The fish eat the copepods and we eat the fish. So our Friday dinners depend upon the diatoms and national prosperity may be determined by the plankton.

Herring on the Atlantic side of Ireland and of Nova Scotia are larger than in the interior waters on the other side. The warmer the water, the saltier the sea, and the greater the amount of oxygen in the water the faster grow the fish. But the oxygen in the water increases with the atmospheric pressure, so the growth of the young herring varies with the barometer.

That is why the biologists of the marine research stations of Wood's Hole on the Atlantic, and La Jolla on the Pacific are continually analyzing the sea water, taking the temperature of the ocean and patiently counting the copepods and diatoms with the microscope.



THOMAS CORWIN MENDENHALL

By whose death, at the age of eighty-two years, America loses a distinguished physicist. Dr. Mendenhall was formerly professor at the Ohio State University and at the University of Tokio, president of the Rose Polytechnic Institute and of the Worcester Polytechnic Institute, superintendent of the Coast and Geodetic Survey and at the time of his death president of the board of trustees of the Ohio State University.

HOT WEATHER CLOTHING

In these days when we are largely occupied in efforts to keep cool, it is worth while to spend a little thought on the fundamental principles of heat movement and how we can apply them to the problem.

In the first place we must remember that our object is not so much to keep the heat out as it is to get the heat out. Our internal stoves, where food serves as fuel, produce heat enough to raise us to the fever point in a few hours and to cause death by what is commonly called "sunstroke," even though there were no sun, if we could not continually pass off our surplus heat to the surrounding air.

The air will consent to relieve us of our surplus heat on two conditions: first, when the air is cooler than our bodies, and, second, when it has less water than it can hold. If the air is above 99 degrees Fahrenheit and has 100 per cent. humidity, there is no help for us.

Fortunately the air roundabout rarely attains these two conditions, but the air that is kept in contact with the skin as by tight or thick clothing does get to the same temperature as the body and does take up all the moisture it can hold. In that case the only thing to do is to get rid of this old air and get in some new that is capable of absorbing heat and perspiration.

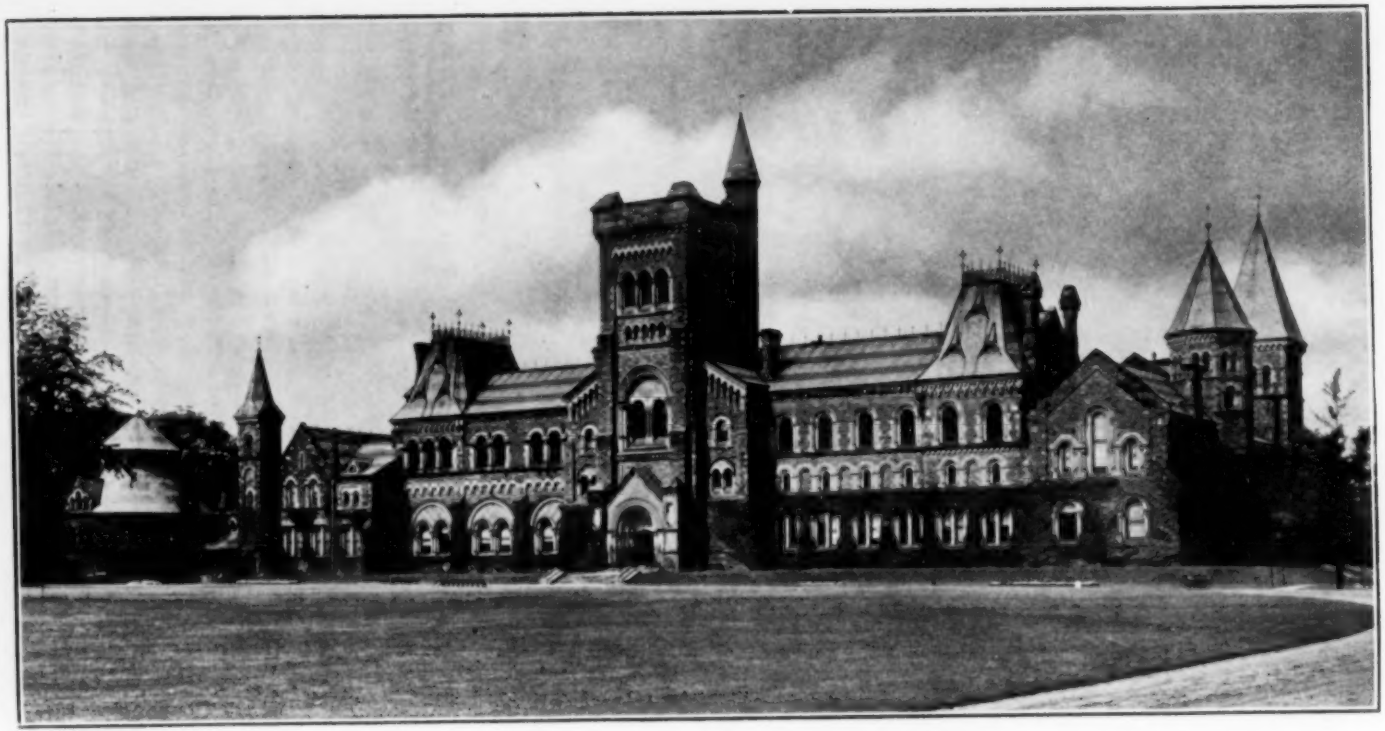
From a purely theoretical point of view, therefore, the ideal midsummer costume would be to wear a large umbrella and nothing else. But to apply a scientific theory without regard to local circumstances is often unwise and sometimes unsafe. Yet whatever deviation from the ideal local custom may require, we should bear in mind the fundamental principle that cooling is due chiefly to evaporation and that evaporation depends upon ventilation. Close clothing keeps a hot and humid layer of air in contact with the skin so that we who rejoice that we dwell in the temperate zone are really living the year around in a tropic atmosphere except for our hands and face. The circulation of air should theoretically be sufficient to keep the skin free from uncomfortable accumulation of perspiration, but not so rapid as to chill it by excessive evaporation. It is not the sweat we see that cools us, but that which passes off unperceived. To evaporate the water from a man's wet clothing may require as many calories as he gets in a day's food.

Clothing halves the loss of heat in cold weather and cuts it down still more in warm weather. The clothed man ranks between the furry dog and the rabbit in the matter of heat exchange.

If our skin were a sheet of silver foil of the same thickness, we should lose heat 2,280 times as fast as we do, but a layer of immobile air, such as may be caught by fur, feathers or close-knit cloth, will retard the loss of heat ten times as much as the skin.

To keep the air in free circulation over the skin, the clothing should touch the skin as little and as lightly as possible. Coarse-meshed and porous fabrics are better than fine cloth.

The weave makes more difference than the color. It is true that black clothing absorbs about twice as much sunlight as white, but that does not tell the whole story, for it is heat that we want to keep out, and more than half of the sun's heat is not seen by the eye as light. We see about an octave of the solar spectrum, from the red waves of lowest frequency to the violet of highest frequency. But beyond the violet there are two



UNIVERSITY COLLEGE, UNIVERSITY OF TORONTO,

Where the British Association for the Advancement of Science and the International Mathematical Congress met in August.

octaves and below the red there are six octaves that we can not perceive with the eye. At high noon in the latitude of Washington, fifty-one per cent. of the energy of solar radiation comes in the form of the dark heat rays of the infra-red, forty per cent. as visible light, and nine per cent. as ultra-violet rays, also invisible but the most powerful of all in their effect on the skin. It is the ultra-violet rays that are responsible for tanning and burning. Now the dark heat rays pass equally well through dark and light cloth, and the ultra-violet chemical rays pass better through light than dark.

Leonard Hill, the great English authority on climatology, commends the Egyptian robes as the most comfortable garments for a hot country for "as the native walks his garments sway and flap in ungainly fashion, but in doing so cause air currents, which have a cooling effect." The missionaries' wives, when called upon to devise a costume for the women of the Pacific Islands, did well from a sanitary point of view when they clothed them in "Mother Hubbards," though they could hardly have done worse from an artistic point of view.

But it is not necessary for clothing to be unbecoming in order to be comfortable. Probably American women have never been more seasonably clad than they are this summer, but no one could call their costumes ungainly. The men, too, although they are more conservative and less original than women in matters of dress, have made some progress of late in the adaptation of their clothing to the summer season, but their tight collars and belts are contrary to the first principles of hot weather costume.

DREAMS TO ORDER

THE interpretation of dreams has been an object of eager interest for more than three thousand years. The latest journals of psycho-analysis deal with the same question as the earliest papyri of Egypt or cuneiform bricks of Assyria—and with little more success.

Isn't it time then that we attacked the problem from the other side? Instead of wasting so much time endeavoring to determine what dreams mean, would we not make better progress if we tried to find out what makes dreams? Then we could get whatever dreams we liked and whenever we liked and need not bother about their interpretation.

We now have some prospect of progress in this direction, for our new knowledge of the hormones gives us a clue. A case in point is reported by Finley. He had a woman patient to whom he gave a grain a day of extract of the pituitary body to build up her blood pressure. Her dreams had hitherto been trivial and colorless, but after ten days of the treatment she began to have pleasurable and highly colored dreams. She traveled extensively in her dreams, as she had always longed to in reality, and wherever she went she found the stations and cars freshly painted in pleasing colors and the trainmen in nice new uniforms with gold braid.

Shortly after the treatment was altered and adrenalin, another of the glandular secretions, was substituted. At once a change came over the spirit of her dreams. They lost their colors and became horrible, filled with violent quarrels.

Now if a Freudian practitioner had taken the case, he would have proceeded to probe for complexes in her unconscious without even putting her under an anesthetic. He would diagnose the former dreams as due

to "suppressed desires," instead of pituitrin, and the latter as due to "infantile fears," instead of adrenalin. Yet the doctor could produce either brand of dreams at will by an infinitesimal dose of white powder.

Fear and rage promote the secretion of adrenalin from the suprarenal glands. Conversely, the injection of adrenalin, which may be made in the laboratory, will stimulate the symptoms of fear, the goose-pimples, the hair-raising, the cold-sweat, and all that. And James showed years ago that with the symptoms come the corresponding emotion.

It seems from this case that dreams may be made to order like picture postcards, one cent plain and five cents colored. Common dreams come plain in black and white and grey, chiefly grey. Most of us are colorblind for a third of our lives. My dreams are usually fragmentary and fugitive, shadowy and colorless. But once when I took laudanum there was unveiled before me a series of the most wonderful pictures, minute and sharp as the landscape seen through the big end of an opera-glass, and as brilliantly colored as a Chinese rice-paper sketch. It was an unprecedented experience for me, and I realized for the first time what delights are enjoyed by the favored few who have colored dreams naturally.

De Quincey in his "Confessions" and Baudelaire in his "Hymn to Opium" depict in the most glowing terms that English and French afford the delights of the opium dream. But those who seek an artificial paradise by way of the alkaloids find ultimately that they have jumped out of ennui into anguish. De Quincey soon found himself chased by Chinese, kissed by cancerous crocodiles, and suffering other forms of alliterative torment.

Opium and hashish in the Orient, alcohol and cocain in the Occident, have been from time immemorial the favorite means of escaping from this dull world into the dreamland of Euphoria. Hashish also intensifies color perception and excites chromatic dreams. I knew a lady who was accustomed to take a pinhead pill of hashish gum before going to the theater because it brightened the scene and converted the painted backdrop into a spacious landscape.

The internally secreted hormones are similar in potency and effect to the externally administered alkaloids. An overdose of insulin, a hormone secreted by the pancreas, causes feelings of "causeless" fear, followed by trembling and finally collapse. The patient can recover his courage by sucking a stick of candy. An excess of activity on the part of the thyroid gland excites anxiety and irritability.

Possibly anxiety and terror dreams in general may be caused by some disturbance in the balance of the hormones or similar organic derangement rather than by anything peculiarly unpleasant in one's past experiences or present predicament.

Certain foods are reputed to produce bad dreams, but this is uncertain. I have often been warned against eating mince pie or Welsh rabbit before bed time, but when I tried the experiment I saw neither hair nor hoof of a nightmare. Nobody ever told me of any foods that would give pleasant dreams. I wonder why. Aren't there any? But some day the chemist may give us synthetic dreams by his synthetic compounds and then shall our sleep always be happy and the nightmare shall be no more.